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THE TRAVELERS RESEARCH CENTER, INC.

MONTHLY PROGRESS REPORT

(Cwb-10704)

August 1963

To the
UNITED STATES WEATHER BUREAU
for

WEATHER DATA PROCESSING RESEARCH AND DEVELOPMENT PROGRAM

7055-00 General Comments

A coordination meeting was held in Washington on 5-6 August 1963 between U.S. Weather Bureau personnel and TRC personnel. Planning milestones under Project 1 were discussed. A second meeting will be necessary before these milestones can be completed. Discussion of the meeting is contained in the project and task writeups.

Information for Project 2 was received from the U.S. Weather Bureau during the month on predictor stations including predictor tables and networks for new stations.

The procedures for borrowing 433L magnetic tapes containing data useful under this USWB program are operating smoothly and several such tapes have been put in use. The determination of ownership of tapes between 433L and the FAA has been accomplished and UAC informed TRC on 29 August that the transfer of the FAA tapes to 433L has been accomplished. FAA tapes required for use under this program have not been available up to the end of August. Requests for loan of these tapes are on file at UAC and the expectation is that they can be acted upon now with the transfer of responsibility from FAA to 433L. Some delays in the work have resulted from this delay in availability of data.

C. Jenkins will assume the computer coordination duties with relation to this program as a part of his function as program coordinator. The size of the program does not warrant the continuation of Mr. E. Gross for assistance in this area. Thus, problems relative to operation on the 7094 at NMC will be handled between C. Jenkins and G. Casely or G. Hardin. To date the NMC computer operation has proceeded smoothly. Arrangements have been made to split the time on the computer on three of the evenings each week in order to make more efficient use of the available time.

7055-00 General Comments (Cont.)

A technical note on studies of atmospheric transmission data is appended to this progress report.

A meeting is planned for 12-13 September in Washington involving USWB personnel and TRC personnel to coordinate work on Project 3 "Enroute Weather - Analysis and Prediction".

Program Coordinator - C. F. Jenkins

7055-10 Project 1, Short-Period Terminal Forecasting

E. Aubert, K. Hage, H. Entrekin, and J. Wilson met with Messrs. R. Allen, C. Roberts, and M. Lefkowitz in Washington on 5-6 August 1963. Familiarization visits were made to the Washington area mesonetwork tower site at Waldorf and to the USWB facilities at Sterling, Va. Discussions were held on problems of data acquisition and processing as required for studies of the basic observation (1, 2 and 5 minute predictions) of atmospheric transmission under Task 1. Details of the discussions and reports on progress in August are presented in the task summaries.

A technical note on the results of studies of transmission, wind and rainfall rate data from the Federal Aviation Agency mesonetwork at Atlantic City is attached to this report.

Summary of work planned for September

Tests of simple persistence and persistence plus trend techniques for 2, 3 and 5 minute predictions of 1 and 2 minute mean transmission values based on digitized observations at 12 second intervals as described under Task 1 will be completed for a small sample and used as a guide for the planning of more extensive processing.

If arrangements can be worked out, further discussions will be held with Messrs. Allen, Roberts, and Lefkowitz in September to establish firm plans for data processing under Tasks 1 and 3.

Project Scientist - K. D. Hage

7055-11 Task 1, Scale Analysis of Terminal Weather Variations

A technical note on preliminary studies of atmospheric transmission data from the Federal Aviation Agency Atlantic City mesonetwork is appended to this report. Much of the work on this note was completed under Contract FAA/BRD-363 and supplements a similar report submitted to the FAA in the April monthly progress report.

7055-11 Task 1, Scale Analysis of Terminal Weather Variations (cont.)

A meeting was held with Weather Bureau personnel on 5-6 August 1963 to obtain their views and ideas concerning the selection of time intervals for predictors and predictands, the data source, data volume, and data reduction and processing methods to be used for studies of the basic observation of transmission. As a result of this meeting, the Weather Bureau tentatively decided to establish a second transmissometer within 3000 feet of the first at the Weather Bureau test site at Sterling, Virginia and to use this area to simulate the approach zone of an airport runway. In conjunction with this it was decided to use data from the two transmissometers located at Dulles International Airport, which is within a few miles of the Sterling test area. Other problems considered but not resolved include the rate at which the transmissometer data should be recorded, the use of digitized wind data to study the variability of per cent transmission, and the time intervals to be used for predictor and predictand information.

As a preliminary step to setting up final data processing procedures to be applied to transmissometer data from the Washington, D. C. mesonet, seven data samples of 12 second transmissometer data from the Atlantic City, New Jersey mesonet of 90 to 120 minutes in length were digitized and processed through a computer program which computes the "root mean square error" between the forecast and actual values. The last 12 second observation and filtered values from 5, 9, and 15 observations were used as predictors to make 2, 3, and 5 minute forecasts. One and two-minute mean values were used as predictands. The results in 5 of the 7 cases showed that the last single observation was the best predictor for all forecast and predictand periods. In the remaining two cases, filtered values of 9 and 15 observations were slightly better. Time series plots of the 12 second transmissometer data are now available for the two cases in which the filtered data produced the best forecasts and for two others. A comparison of these suggest that the introduction of "trend" as a predictor might further reduce the forecast errors.

Summary of work planned for September

In September, a high pass filter will be applied to the data discussed above and compared to the previous results. This should provide further evidence as to the usefulness of "trend" as a predictor.

A second meeting will be held with the Weather Bureau in early September to complete the plans for data reduction and processing procedures to be applied to transmissometer data from the Washington, D. C. mesonet.

Task Scientist - H. Entrekin

7055-12 Task 2, Radar Data Utilization

The computer program for computing revised values of the orientation and characteristic length of echoes has been finished and is presently being applied to the digitized echo distributions for the eleven storms previously collected with the

7055-12 Task 2, Radar Data Utilization (cont.)

Atlantic City WSR-57 and the two storms collected with the Oklahoma City WSR-57.

In general, the revised characteristic lengths are shorter than the ones computed earlier by the Statistical Properties Program, and are in excellent agreement with the average echo length determined by manual measurements.

In preparation of screening regression runs for determining echo predictability using echo statistical properties as predictors; Jim Cole has found that several of the statistics are interdependently related. Examination of preliminary data has suggested some non-linear functions of predictors which should be included.

Summary of work planned for September

1. Complete computer runs at NMC for determining revised orientation and characteristic lengths.

2. Complete comparison of revised characteristic lengths with manually measured average lengths.

3. Prepare screening regression runs to determine echo predictability using both linear and non-linear combinations of the echo statistical properties as predictors.

7055-13 Task 3, Prediction Technique Development

Work on Task 3 was limited to a review of subjects to be discussed with representatives of the U.S. Weather Bureau at a proposed meeting in September.

Summary of work planned for September

1. Meet with representatives of the U.S. Weather Bureau to decide upon prediction and verification techniques to be studied under Task 3.

2. Prepare specification for verification programs or other program modifications necessary to complete task assignments.

3. Initiate program changes or additions.

Task Scientist - A. Boyer

7055-20 Project 2, Medium-Period Terminal Forecasting

All three tasks are on schedule. The work done is described in the task writeups, except for one item. The screening regression programs previously written for the IBM 7090 were changed to take advantage of the IBSYS system on the IBM 7094. The changes are about 90 per cent complete. The final versions of these programs will take less time on the IBM 7094 than would the original programs. The cost of the changeover, two man-weeks, will be borne by Project 2 although the programs will be used in all three projects.

Summary of work planned for September

1. See task writeups.

2. There is some evidence that the screening programs are faster than the one now being used by Weather Bureau personnel, but more information is required. This will be pursued in September.

Project Scientist - I. Enger

7055-21 Task 1, Statistical Technique Engineering

In the course of carrying out a program of development it is necessary to lay plans which at the time are believed to be best for satisfying the goals of the project. Such has been the case in the development of MDA and screening canonical correlation. The function of the latter procedure was introduced for the purpose of producing more efficient prediction methods. It is our belief that during the monthly period just passed we have succeeded in developing a new approach which will enable us to produce ceiling and visibility probability forecasts as accurately as MDA and far more efficient than those hoped for with the introduction of canonical correlation. Although the method does not involve profound mathematics (it uses a regression structure) it takes advantage of our present mode of calculation (high speed computers).

We are now engaged in a feasibility study of this approach which is being conducted on a case previously subjected to a full-scale MDA analysis. This should be completed within two or three weeks. Thus far the results look comparable to MDA.

The impact of this new approach, in the event it proves successful, is this: we should be able to perform our initial statistical analyses on the historical samples in about one tenth the time taken by MDA analysis and prediction, and we should be able to make real time forecasts very efficiently because of the additive structure of regression versus the multiplicative structure of distance neighborhoods in MDA.

Summary of work planned for September

In anticipation of the success of this new approach a new computer program is being written. The screening canonical correlation program has been suspended temporarily.

Task Scientist - R. G. Miller

7055-22 Task 2, Statistical Prediction for New Terminals

1. This project is concerned with developing and evaluating the multiple discriminant analysis (MDA) statistical procedure for forecasting ceiling and visibility for 2, 3, 5, and 7 hr at Chicago, Seattle, San Francisco, and Los Angeles and for forecasting integrated operating conditions (IOC) for 2-7 hr at San Francisco. The variables to be forecasted are termed predictands, a specific element at a specific station for a specific forecast length. Examples are 2-hr ceiling at Chicago, 3-hr ceiling at Chicago, 2-hr IOC at San Francisco, etc. There are 40 predictands, ceiling and visibility at four stations for four forecast lengths and IOC at San Francisco for four forecast lengths. The MDA procedure treats each predictand separately so 40 forecast systems will be developed. Also, the MDA procedure results in a probability forecast of the occurrence of classes of a predictand. Therefore, the first job is to specify the predictand classes. This has been done by the Weather Bureau and Mr. Allen has furnished us with the following classes:

Table 1
Predictand Class Limits for ORD, SEA, SFO, LAX

Class No.	Ceiling (Hundreds of Feet)	Visibility (Miles)	Integrated Operating Conditions* CIG	VIS
1	≤ 1	$\leq \frac{3}{8}$	≤ 1	$\leq \frac{3}{8}$
2	2-4	$\frac{1}{2} - 1\frac{3}{8}$	2-4	$\frac{1}{2} - 1\frac{3}{8}$
3	5-9	$1\frac{1}{2} - 2\frac{1}{2}$	5-9	$1\frac{1}{2} - 2\frac{1}{2}$
4	10-29	3-4	10-29	3-4
5	≥ 30	≥ 5	≥ 30	≥ 5

*SFO only. The lowest class possible is always used, e.g., if CIG = 3 and VIS ≥ 5, then IOC class is 2.

2. Mr. Roger Allen and I visited Weather Bureau forecast offices in Chicago, Seattle, San Francisco, and Los Angeles. Two days were spent at each station and the procedure was the same. We first talked to the meteorologist-in-charge (MIC) and the research forecaster (or principal aviation forecaster) outlining the project. Then, the MIC called a meeting of all forecasters not on duty. Mr. Allen outlined the history, objectives, and procedures of this task. I described the multiple discriminant analysis forecast procedure, including the collection and preprocessing of surface data. The presentations by both Mr. Allen and myself were repeated several times to cover forecasters on all shifts. The interest, cooperation, and enthusiasm of the forecasters was extremely gratifying. There appears to be an attitude of receptivity toward objective forecast methods and an appreciation of both

7055-22 Task 2, Statistical Prediction for New Terminals (cont.)

the advantages and shortcomings of such methods.

The forecasters were asked to assist us by utilizing their experience to choose the predictor variables for forecasting ceilings and visibility for 2-, 3-, 5-, and 7-hr with emphasis to be placed on bad weather. There are three items involved: first, the forecasters need to specify a network of stations; then the variables at each station in the network; and, finally, a set of limits for each variable.

3. The station network choices were received by Mr. Allen during the month. He has checked them and supplied us with the following:

Table 2
Predictor Station List

Predictand Station	Chicago (ORD)		Seattle (SEA)		San Francisco (SFO)		Los Angeles (LAX)	
Forecast Lengths (hrs.)	2,3	5,7	2,3	5,7	2,3	5,7	2,3	5,7
	ORD	ORD	SEA	SEA	SFO	SFO	LAX	LAX
	MDW	MKE	BFI	OLM	OAK	OAK	NTD	NTD
	NBU	MKG	TCM	WYI	NGZ	NGZ	BUR	BUR
Predictor	MKE	SBN	OLM	TTI	SRF	NUQ	NTB	NTB
Stations	MKG	PIA	NEJ	YKM	NUQ	SUU	SDB	SDB
	SBN	RAN	WYI	PAE	SUU	SRF	SBD	SBD
	PIA	MLI	TTI	BLI	SAC	SAC	EDW	EDW
	RAN	MSN	YKM	PDX	MRY	FAT	NZJ	NZJ
	MLI	GRB	PAE	EUG	RBL	RNO	NZY	NZY
	MSN	SPI	BLI	BFI	ACV	ACV	BFL	DAG
	GRB	IND	PDX		FAT	RBL	DAG	BFL
	SPI	BRL			RNO	MRY		
						PDX		

4. Near the end of the month the predictor variables and limits were received for Seattle and San Francisco. These will be examined in September.

5. Concurrently with the work described above, preliminary data processing is being carried on. The end-product will be four sets of data, one for each predictand station, containing 10,000 values of each of a large number of variables. There are six steps:

7055-22 Task 2, Statistical Prediction for New Terminals (cont.)

a. Ten years, 1949-58, of hourly observations are obtained for the stations listed in Table 2. The data are on IBM 7090 magnetic tape—two tapes per station. Most of these were on hand and the remainder were secured from Asheville by the Weather Bureau and furnished to us.

b. Data for 15 stations were received quite a while ago on IBM 705 tapes. These need to be converted to a format similar to the rest of the stations. This is done by running the SBC program which takes some 36 minutes of computer time per station. In August, eight stations were completed.

c. After all tapes are in the same format they need to be run through a second program, entitled GDVP. This takes about 45 minutes per station. This program does a great deal of processing, too much to describe in detail, but the end-product is two tapes containing a number of variable vectors for one station, a listing of 87,648 values of each predictor in chronological order. To date five stations have been run through GDVP.

d. The GDVP tapes need to be merged onto other tapes where one tape contains data for four stations. There is no processing of data, this is just a mechanical copying which later on saves computer time. The program did not work when first tried on the Washington computer but it was corrected in August and run successfully once.

e. The merged tapes then need to be run through the Error-Frequency program. This counts the number of missing and erroneous values for each variable by month and by hour of the day. This information is used to delete variables which are missing for long periods of time or missing more at night than in the day, etc. This program has not been run yet.

f. Finally, the GDVP merged tapes need to be run through the SORDID program which generates a network tape. None of this was done in August.

6. A number of computer programs required for this task are being taken from the previous FAA contract. However, several of them are not complete. These are being completed by programmers of the United Aircraft Corporation. They devoted some effort to this during August and more will be needed in September.

Summary of work planned for September

1. The predictor variables and limits furnished by the forecasters at all four stations should be on hand. These will be examined and evaluated.

2. The major portion of manpower will be devoted to data processing and computer programming. See paragraphs 5 and 6 above.

Task Scientist - I. Enger

7055-25 Task 5, Development of Derived Predictors

The purpose of this task is to try to improve the forecast results obtained with the Multiple Discriminant Analysis (MDA) procedure in forecasting ceiling and visibility at forecast lengths of 2, 3, 5, and 7 hours. The MDA procedure has previously been developed using "raw predictor" variables only. The term, raw predictor variable, as used here, refers to an element of the standard airways observation as recorded on WBAN-10 A and B. Further the MDA forecast procedures developed to date use zero time data, that is, data from the single hour at which the forecast is made.

The basic premise underlying this attempt to improve the results obtained thus far is that the use of more complex functions of the hourly surface variables such as space gradients and time derivatives--approximated by finite differences--etc., will, by increasing the information content of the predictor set, lead to sharper differentiation between predictand categories and improve the performance of the technique on rare events.

To this end we are obtaining the aid of the terminal forecasters at the two stations (IDL and DCA) to which this experimental program is confined.

Comments and suggestions with respect to the forecasting of ceiling below 500 ft and/or visibility below one mile were received from the Idlewild forecast personnel. These were well thought-out comments and the cooperation of this forecast unit is much appreciated.

The comments and suggestions were reviewed at TRC in the light of available data. There appear to be five rather broad classes of problem situations.

a. The advection stratus-fog situation.

b. The E-W warm front moving northward from south of the area.

c. The N-S occlusion (principally warm type) moving eastward.

d. Major Storm systems.

e. Radiation situation (to a lesser extent).

A meeting was held at Idlewild on August 21. At this meeting the comments and suggestions were discussed with the following Weather Bureau personnel: Messrs. Allen, Kaplan, Zucker, Morgan, Stone, Schor. Consideration was given to the use of Boolean, or combination, terms to index each of the above mentioned critical situations. The degree of effectiveness with which this indexing can be accomplished appears likely to be determined to a large extent by our collective ability to specify critical ranges of spacial differences, etc. Preliminary statistical analysis of the data will be necessary.

7055-25 Task 5, Development of Derived Predictors (cont.)

There appears to be little reason to depart appreciably from the initial rough outline for this task except that it now appears unlikely that we will be able to obtain sea-surface temperature measurements taken at the Ambrose lightship. These data are not available at Asheville for a sufficiently long period of time.

Milestone 1 of this task was not completed in August due to the inability of scheduling a meeting with the Terminal Forecast Unit at DCA.

Summary of work planned for September

The work will continue on developing derived predictors. This will include the selection of derived predictors, initial indexing of critical situations, evaluation of the effectiveness of derived predictors and indices, construction of frequency distributions of predictors and indices, and investigation of predictor-predictand relationships to maximize the effectiveness of the dummy variable procedure.

The work outlined above will be conducted concurrently with the development of the individual data samples. The development of data samples will involve the specification of a network of predictor stations with careful consideration of the raw predictor data to be included at each station in order to permit the derivation of the required complex predictors. Careful consideration must be given to the distribution of errors in the selection of raw predictor data in order to minimize the biasing effect of the logical union of errors. This will necessitate some computer editing of data before the final establishment of 10,000 hours of error-free data and output of the network data sample.

The Weather Bureau will continue their efforts to obtain sea-surface temperature data from the Ambrose lightship.

Arrangements will be made to visit the Terminal Forecast Unit at Washington International Airport to discuss Task 5 with the forecast personnel and to obtain their suggestions for incorporation into the derived predictor task.

Task Scientist - J. E. MacMonegle

7055-30 Project 3, Enroute Weather - Analysis and Prediction

Dr. Cooley has been away on travel and vacation for three weeks, beginning August 9.

Mr. Ball visited the SELS unit at Kansas City on 21 August to obtain information on the current IBM 1620 computer programs being used in the prediction of hazardous weather. The trip was continued at Offutt AFB on 22-23 August where a more detailed knowledge was acquired of the operational analysis and forecasting procedures being used by AWS in support of SAC. This trip was made under the requirement that current procedures in use at NMC and Prediction Centers of the Armed Services be examined to determine their suitability for the National Aviation Meteorological System.

Mr. Erickson traveled to NAFEC, Atlantic City, New Jersey on 13-14 August, for the final checkout of the ADIS-2 Developmental Program using a large data sample.

The detailed work of the project is described in individual task writeups.

Summary of work planned for September

Dr. Cooley, Mr. Jenkins and Mr. Ball are scheduled to visit Washington on 12-13 September to discuss Project 3 problems and plans with USWB personnel. Individual tasks contain detailed planning for September.

Project Scientist - D. Cooley

7055-31 Task 1, Analysis of Inflight Weather Elements

The final checkout of the ADIS-2 Developmental Program was achieved. This program modifies the original ADIS-2 system so that more than 1 hour of data can be processed in a single run and may be written on output tape in packed or unpacked format. The processed data includes information on cloud type and convective activity not available in previous data collections processed by ADIS-1. The program was checked out under another contract on 360 hours of data in the period 15 February 1963 through 13 April 1963. The collection in this period was made on hourly, 3-hourly and 6 hourly cycles. These data are available for use under this contract. A write-up on the operational use of this program by P. Lowe, UAC was modified and put in final form.

Specifications were completed for the Special ADIS-2 Item Separator Program. The coding of this program by Mr. Saunders, Programmer on Project 3, was initiated. This program is necessary to prepare data obtained from the ADIS-2 Developmental Program into a form suitable for input to various preprocessor and analysis programs to be used in Project 3. Some special features of this program are: (1) it accepts an input tape with a variable number of records for each hour of data, (2) more than 8 parameters can be processed by the program, although a maximum of 8 parameter tapes can be written simultaneously and (3) a particular parameter can be processed on any time cycle rather than for every hour of input data.

7055-31 Task 1, Analysis of Inflight Weather Elements (cont.)

Specifications for the preprocessor and analysis programs for convective cloud type are nearly complete. The programs will be general enough so that low, middle and high cloud type routinely obtained as output from the ADIS-2 Program in an item-separated format can be processed and analyzed. The preprocessor program for cloud type will utilize features common to existing preprocessor programs for other parameters with suitable modifications. The analysis program will consist of a single pass weighted-average procedure that has previously been used in analyses of cloud amount and height, visibility, and precipitation occurrence and type. The initial use of the cloud type preprocessor and analysis programs will be to obtain a gridpoint analysis of low cloud type indicating areas of convective activity. More general cloud type analyses could be accomplished at a later date using the existing program.

Work began on milestone 5, Hazardous Weather Diagnostic Program Specifications. Initially, an effort is being undertaken to evaluate the adaptability of procedures currently in use at NMC and other Weather Prediction Centers to the National Aviation Meteorological System.

A verification test of screening regression equations for the specification of low cloud amount and normalized cloud height from other parameters has been run on the IBM 7094 at NMC. Mr. Marshall Atwater will analyze the results of the verification. The equations were developed under the FAA program on a 360-case sample from October to December 1962. They are being tested on an independent sample of 290 cases from January 1963.

Summary of work planned for September

The coding of the Special ADIS-2 Item Separator Program is to be completed and checkout of this program will begin. The specifications for the preprocessor and analysis programs for convective cloud type will be completed and coding of the program will start. The examination of current analysis and forecasting procedures in operational use at various Weather Prediction Centers will continue.

Task Scientist - J. Ball

7055-32 Task 2, Enroute Weather Prediction

Mr. Atwater is analyzing the verification of 3- to 12-hr statistical forecasts of low cloud amount and normalized cloud height on both the developmental sample from October-December 1962 and the independent sample of January 1963 to determine the synoptic situations in which the predictions seem most likely to fail. Mr. Saunders, the programmer on Project 3, is preparing a new data selection program for preparing input samples for development of generalized statistical prediction operators.

Summary of work planned for September

Plans for September call for processing more of the 1962 data to attempt to improve the cloud prediction equations by adding other kinds of predictors.

Task Scientist - D. Cooley

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(Cwb-10704)

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Appendix A
Percent Complete On Milestones For
Weather Data Processing
Research and Development Program

Project 1. Short-Period Terminal Forecasting

Item	Title	Start	Finish	Percent Complete
	Task 1. Scale Analysis of Terminal Weather Variations			
C1.	Preparation of a plan for the reduction and processing of high frequency multiple observations of atmospheric transmission on a runway for the purpose of minimizing the errors of persistence for 1, 2, and 5 min. periods.	1 Jul 63	1 Sep 63	50*
	USWB review and approval of Item C1.	1 Aug 63	1 Sep 63	0*
C3	Application of the processing procedures defined under C1 to existing digitized runway observations at ACY.	1 Sep 63	1 Feb 64	0
C4.	Acquisition and/or reduction of suitable high frequency observations from multiple runway transmissometer installations in the DCA mesonetwork region.	1 Sep 63	1 Feb 64	0
C5.	Application of the processing procedures defined under C1 to DCA region.	1 Feb 64	1 Apr 64	0
[illegible]	Report on the results of C3 and C5.	1 Apr 64	1 Jun 64	0
[illegible]	Acquisition and/or reduction of observations from DCA mesonetwork transmissometer observations following procedures under C13.	1 Oct 63	1 Oct 64	0

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* See Page 3 for discussion relative to these milestones

Item	Title	Start	Finish	Percent Complete
Task 2. Radar Data Utilization				
1.	Radar data collection at Atlantic City and elsewhere.	1 Jul 63	1 Jan 65	0
2.	Studies of objective measurement of advection.	1 Jul 63	1 Jul 64	5
3.	Studies of objective measurement of predictability.	1 Jul 63	1 Jul 64	10
4.	Refinement of radar data processing programs.	1 Sep 63	1 Nov 64	30
5.	Testing of refined techniques.	1 Oct 63	1 Jun 65	5
6.	Relation of radar data with reports of severe weather.	1 Jul 63	1 Apr 65	0
8.	Technical report on advanced techniques for processing digitized radar data.	1 Mar 64	1 Jul 64	0
9.	Technical report on status of weather radar interpretation and prediction.	1 Apr 64	1 Aug 64	0
Task 3. Prediction Technique Development				
	(Items 1 through 5, and Items 10, and 12 are applicable for technique development with data from either the DCA or ACY mesonetworks).			
1.	Obtain class limits and other information from the USWB for developing forecasting system for atmospheric transmission, cloud base height, and wind vector.	1 Jul 63	1 Sep 63	0*
2.	Prepare plan for 0-1 and 0-2 hour forecast evaluation (transmission, cloud base height, and wind vector).	1 Sep 63	1 Nov 63	5
3.	USWB review and approval to Item 2.	1 Oct 63	1 Nov 63	0

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* See Page 4 for discussion relative to this milestone.

Item	Title	Start	Finish	Percent Complete
Task 3. Prediction Technique Development (Cont.)				
.	Modify translation program 1 as required for use on USWB IBM 7094 computer with input data in the format provided by the Government and with evaluation procedures established under Item 2.	1 Sep 63	1 Jan 64	0
9.	Modify translation program 2 as required for use on USWB IBM 7094 computer with input data in the format provided by the Government and with evaluation procedures established under Item 2.	1 Oct 63	1 Jan 64	0
10.	Modify translation program 3 as required for use on USWB IBM 7094 computer with input data in the format provided by the Government and with evaluation procedures established under Item 2.	1 Nov 63	1 Feb 64	0
12.	Establish procedures for the selection of translation vectors as appropriate from supplementary radar data, upper-level wind data, or low-level wind data for use with translation Models 2a and 2b.	1 Jan 64	1 Feb 64	0
C1.	Obtain edited DCA mesonetwork observations on punched cards from USWB (15 or 30 min. observational cycle) for selected events in the fields of atmospheric transmission, cloud base height, and wind vector.	1 Oct 63	1 Nov 64	0
C2.	Produce 2-hr forecasts using DCA mesonetwork data with translation Models 1a and 1b.	1 Nov 63	1 Dec 64	0
C3.	Generate translation vectors according to Item 12 from supplementary meteorological observations in the DCA mesonetwork area.	1 Jan 64	1 Jan 65	0
C4.	Produce 2-hr forecasts using DCA mesonetwork data with translation Model 2a.	1 Jan 64	1 Jan 65	0
C5.	Preliminary report on results of Items C2 and C4.	1 Aug 64	1 Nov 64	0

Item	Title	Start	Finish	Percent Complete
Task 3. Prediction Technique Development (Cont.)				
C6.	Produce 60-min. forecasts of transmission with data acquired under Task 1, C15, with translation Models 1a, 1b, 1c, 2a, 2b.	1 Feb 64	1 Apr 65	0
C7.	Preliminary report on results of Item C6.	1 Dec 64	1 Mar 65	0

Project 2. Medium-Period Terminal Forecasting

Item	Title	Start	Finish	Percent Complete
Task 1. Statistical Technique Engineering				
4.	Complete programming of screening canonical correlation (SCC).	1 Jul 63	1 Sep 63	15 *
5.	Use SCC to test for redundancy in time (i.e., is it necessary to develop separate forecast systems for 2, 3, 4, 5, 6...hr projections of the same element?)	1 Sep 63	1 Jan 64	0
Task 2. Statistical Prediction for New Terminals				
1.	Obtain class limits and other information from USWB for developing MDA forecast systems of ceiling and visibility at four stations including IOC at SFO.	1 Jul 63	1 Sep 63	90 **
2.	Prepare plan for 2-7 hr evaluation at four stations (ceiling, visibility, and IOC).	1 Sep 63	1 Oct 63	10
3.	USWB review and approval of Item 2.	1 Oct 63	1 Nov 63	0
4.	Generate MDA forecast system as required in Item 2.	1 Jul 63	1 Feb 64	10
5.	Generate climatological expectancy of persistence (CEP) tables as required in Item 2.	1 Nov 63	1 Feb 64	0
6.	USWB collect and decode subjective forecasts and supply on punch cards as required in Item 2.	1 Nov 63	1 Apr 64	0

* See Page 5 for discussion relative to this milestone.

** All information not received as of the end of August.

Item	Title	Start	Finish	Percent Complete
Task 2. Statistical Prediction for New Terminals (Cont.)				
7.	Produce and verify forecasts on an independent sample as required in Item 2.	1 Feb 64	1 Aug 64	0
8.	Report on the verification in Item 7.	1 Jul 64	30 Sep 64	0
Task 5. Development of Derived Predictors				
1.	Consult with USWB on additional derived predictors to use with MDA.	1 Jul 63	1 Sep 63	50*
2.	Selection of derived predictors to use with MDA (time changes, space gradients, averages, etc.).	1 Jul 63	1 Oct 63	40
3.	Generation of IDL and DCA network tapes containing raw and derived predictors, with ceiling, visibility and amount of low clouds as predictands.	1 Sep 63	1 Nov 63	0
4.	Generate MDA forecast system using a selection of raw and simple derived predictors (time changes, space gradients, and averages, advection, and translation).	1 Nov 63	1 May 64	0
5.	Produce forecasts with systems of Item 4. above; compare these with similar forecasts produced from raw predictors only.	1 May 64	1 Aug 64	0
6.	Prepare technical report on Items 1 through 5 above.	1 Jul 64	30 Sep 64	0

Project 3. Enroute Weather - Analysis and Prediction

Item	Title	Start	Finish	Percent Complete
Task 1. Analysis of Inflight Weather Elements				
3.	Cloud Diagnostic Studies.	1 Jul 63	1 Apr 64	10
4.	Technical Report Cloud Diagnostics.	1 Apr 64	1 Jul 64	0
5.	Hazardous Weather Diagnostic Program Specifications.	1 Aug 63	1 Apr 64	5

* Consultation not yet held with DCA forecasters due to vacation schedules.

Item	Title	Start	Finish	Percent Complete
	Task 1. Analysis of Inflight Weather Elements (Cont.)			
6.	Prepare convective cloud type analysis program.	1 Jul 63	1 Jan 64	15
7.	Prepare convective weather type analysis program.	1 Oct 63	1 Apr 64	0
9.	Development test of Analysis of Convective Cloud Type.	1 Mar 64	30 Sep 64	0
	Task 2. Enroute Weather Prediction			
1.	Formulation 0-9 hr Enroute Cloud Prediction Problem.	1 Jul 63	1 Oct 63	30
2.	Prepare input data processing program.	1 Sep 63	1 Jan 64	0
3.	Development testing 0-9 hr enroute prediction.	1 Jan 64	1 Aug 64	0
4.	Technical Report on 0-9 hr Enroute Prediction (layer 1 Cloud Amount and Height).	1 Aug 64	30 Sep 64	0

FURTHER STUDIES OF ATMOSPHERIC TRANSMISSION DATA FROM THE FEDERAL AVIATION AGENCY ATLANTIC CITY MESONETWORK

(This Technical Note has been prepared under United States Weather Bureau Contract CWB10704 and covers work initiated under Federal Aviation Agency Contract FAA/BRD-363).

K. D. Hage
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30 August 1963

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1.0 INTRODUCTION

A technical note (2) on the results of preliminary analyses of transmissometer data taken during 8 data collection periods at the automatic weather observing mesonetwork of the Federal Aviation Agency at Atlantic City, New Jersey, was issued in April, 1963. Ten additional data collections have been examined for occurrences of low and variable transmission. The results are presented in this report.

Not all of the station locations listed and illustrated in reference (1) are precise. A revised map based on more recent location data provided by the Federal Aviation Agency (4) is shown in Fig. 1. The location of the NAFEC runway transmissometers with respect to mesonet station 1 are included. Selected separation distances and orientations of station pairs are given in Table 1. A list of storms, stations, and remarks on the quality of the transmissometer data is given in Table 2. Because the transmission observations on 20 March, 9, 18, and 22–23 April were relatively high and unchanging these data collections are given no further consideration in this report.

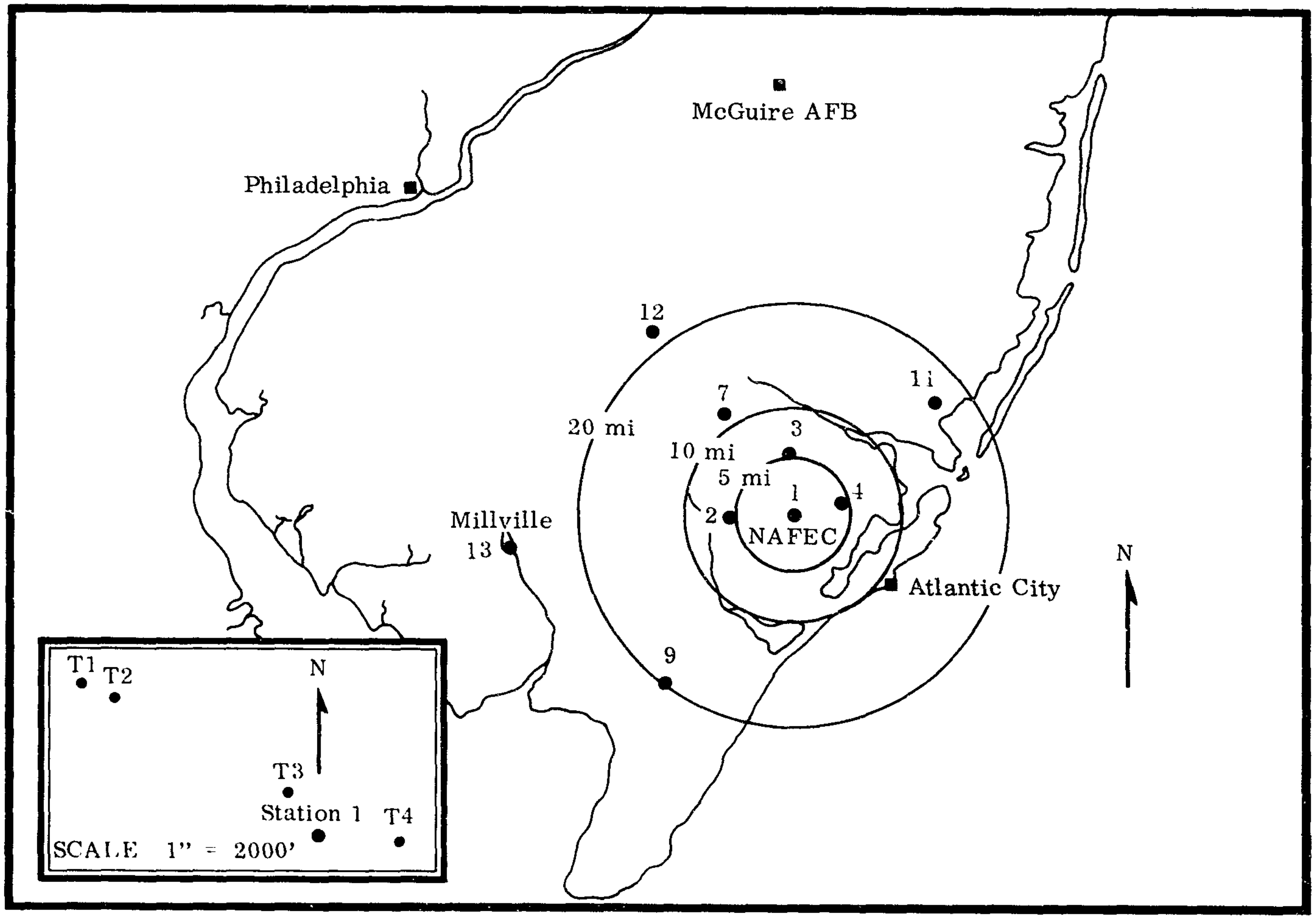

Fig. 1 Location of mesonetwork stations and NAFEC runway transmissometers in relation to Mesonet station 1.

TABLE 1
STATION LOCATION DATA

Station pair A	Station pair B	Separation distance (Stat. miles)	Orientation (Station A to Station B) (360° = N)
T4	T3	0.6	300
T4	T2	1.5	300
T4	T1	1.7	300
T2	T1	0.2	300
1	T4	0.4	273
1	2	6.0	270
1	3	6.1	361
1	4	4.3	78
1	7	12.1	323
1	9	20.0	217
1	12	22.5	322
1	11	17.0	50
1	13	27.5	260

TABLE 2
LIST OF STORMS

Date	Time interval	Stations	Remarks
18 Jan.	180000-190000	T1, T2, T3, T4	Complete data
	180044-182312	1	Partial data
	180930-182036	4	Transmissometer inoperative
	180045-182313	7	Partial data
4-5-6 Mar.	041600-061930	T1, T2, T3, T4	Complete data
	041600-061930	1	Complete data
	041603-061149	3	Partial data
	041605-061850	7	Variable time correction
	041600-061906	12	Variable time correction
	051008-052005	13	Complete data
19-20 Mar.	191600-201400	T1, T2, T3, T4	Complete data
	191633-201319	1	Complete data
	200011-201313	4	Transmissometer inoperative
	191631-201135	7	Complete data
	191634-192353	12	No data during low transmission
	191633-201320	13	Complete data
20 Mar.	201800-202200	T1, T2, T3, T4	Complete data
	201849-202151	1	Garbled data
	201849-202152	12	Transmission > 85%
26-27 Mar.	261800-270300	T1, T2, T3, T4	Complete data
	261855-270046	1	Complete data
	261855-272301	3	Partial data
	261855-270114	4	Transmissometer inoperative
	261855-270224	7	Complete data
	261855-270224	9	Complete data
	261855-270234	12	Complete data
1-2 Apr.	011200-021100	T1, T2, T3, T4	Complete data
	011217-011535	1	Data missing during fog
	011222-021946	2	Variable time correction
	011431-021101	3	Complete data
	011222-021100	4	Transmissometer inoperative
	011228-021100	9	Transmissometer malfunction
	011232-021100	12	Variable time correction
	011235-021100	13	Complete data

Date	Time interval	Stations	Remarks
3-4 Apr.	031800-040800	T1, T2, T3	Complete data
	031804-040738	2	Complete data
	031819-040753	3	Complete data
	031809-040145	4	Transmissometer inoperative
	031854-040756	7	Complete data
	031804-040751	9	Transmissometer malfunction
	031805-040729	11	Complete data
	031804-040749	12	Complete data
	031803-032345	13	Complete data
9 Apr.	090200-091000	T1, T2, T3, T4	Transmission > 85%
	090225-091000	2	Transmission > 85%
	090225-091000	3	Transmission > 85%
	090225-091000	9	Transmission > 85%
	090225-091000	11	Transmissometer inoperative
	090225-091000	13	Transmission > 85%
18 Apr.	180600-181200	T1, T2, T3, T4	Transmission > 85%
	180636-181113	1	Transmission > 85%
	180636-181120	2	Transmission > 85%
	180636-181120	3	Transmission > 85%
	180636-181120	4	Transmissometer inoperative
	180636-181121	7	Transmission > 85%
	180636-181121	9	Transmission > 85%
	180636-181121	12	Transmission > 85%
	180636-181122	13	Transmission > 85%
22-23 Apr.	221800-232240	T1, T2, T3, T4	Transmission > 85%
	221800-232240	3	Transmission > 85%
	221800-232240	4	Transmissometer inoperative
	221800-232240	9	Transmission > 85%
	221800-230355	12	Transmission > 85%
	221800-230819	13	Digital clock inoperative

2.0 FOG–18 JANUARY 1963

A low overcast during the early morning hours on 18 January at Atlantic City, N. J. slowly descended and became fog by 0600. Rain commenced at 1200 and the visibility increased temporarily only to lower once again as the rain ended. Surface wind directions were variable and wind speeds were less than 5 knots except during the break in fog from 1200 to 1500.

A previous study of the movement of the field of transmission along a runway (3) indicated that only a small fraction of the variance of transmission at a fixed point could be explained by translation of the field if the observed wind speeds were less than 4 to 5 mph.

The observed resultant wind from mesonetwork station 1 (Atlantic City) from 1500 to 1700 on 18 January was 070° at 1.6 mph. If allowance is made for the finite starting speed of the anemometer it is probable that the true mean wind speed was 4 mph or less. Transmission values at transmissometers T1 and T4 along the runway at Atlantic City and at mesonetwork station 7 during the onset of fog are shown in Fig. 2. The apparent gross movement of the transmission field during this period was from T1 to T4 to station 7. This was completely inconsistent with translation of the field in the low-level easterly air flow which would have resulted in an apparent movement from T4 to T1 to station 7. Observations at transmissometers T2 and T3 between T1 and T4 were used to resolve the apparent inconsistency.

According to the results of a previous study (3) estimates of the speed of movement of the transmission field from one station to another can be derived from the quantities $r(x, \tau)$ and $r^2(x, \tau) - r^2(0, \tau)$ where $r(x, \tau)$ is the linear correlation coefficient between observations τ minutes apart at stations separated by a distance x and $r(0, \tau)$ is the correlation for a similar lag time τ at the downstream station. Under certain conditions the speed of movement is bounded by $c_1 = k/\tau_1$ and $C_2 = k/\tau_2$ where τ_1 and τ_2 are given by

$$\frac{\partial r^2}{\partial \tau} (x, \tau) = 0 \tag{1}$$

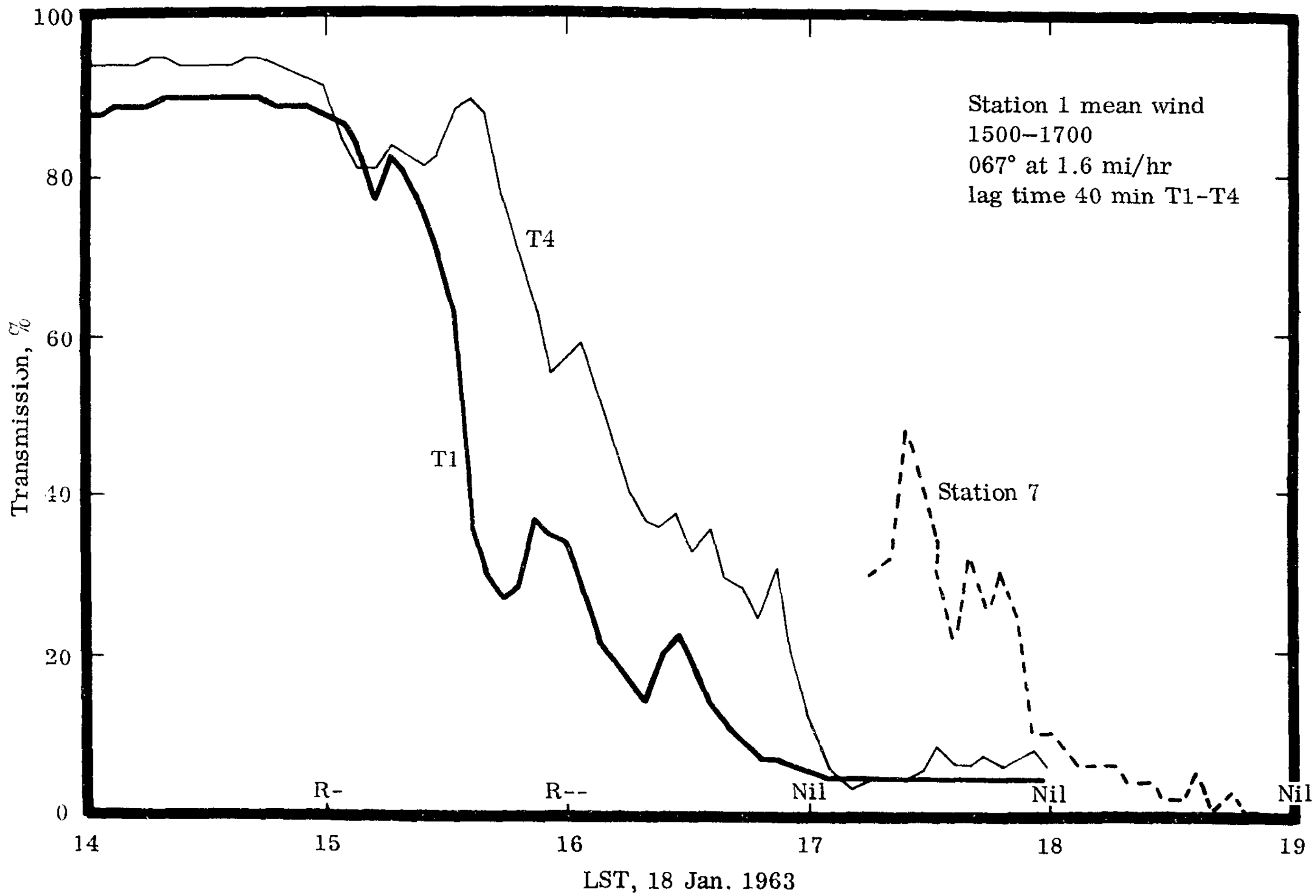

Fig. 2. Transmission observations in fog and hourly precipitation reports from Atlantic City, N. J., on 18 January, 1963.

$$\frac{\partial}{\partial \tau} \{r^2(x, \tau) - r^2(0, \tau)\} = 0 \qquad (2)$$

The criteria represented by Eqs. (1) and (2) were applied to the time series observations of transmission at the station pairs T1–T2 and T1–T4. The correlation curves are shown in Fig. 3. Both pairs of correlation curves in Fig. 3 indicate the existence of time variations in transmission that can be accounted for either by translation of the field from the southeast (T2 to T1 and T4 to T1) or by translation of the field from the northwest (T1 to T2 and T1 to T4). However, for short times and station spacing (T1 to T2) the maximum amount of variance that can be explained by linear translation is achieved with movement from the southeast in the direction of the wind. At longer times and station spacing (T1 to T4) the maximum explained variance resulted from movement in the opposite sense. The details of the transition from predominantly advective to predominantly non-advective processes can be seen from the transmission curves in Fig. 4. The minor minimum transmission value at about 1515 at T4 intensified rapidly as it moved to T3, T2, and T1. The net effect of rapid intensification of small scale features such as this was an apparent movement of the transmission field in the opposite sense or growth of fog into the wind along the runway as seen in Fig. 2. In view of the results in references (2) and (3) this is not a common occurrence with surface wind speeds in excess of 4 to 5 mph at Atlantic City. Though incomplete, the curve for station 7 in Fig. 2 suggests that the rate of fog development observed along the runway did not continue between T1 and station 7.

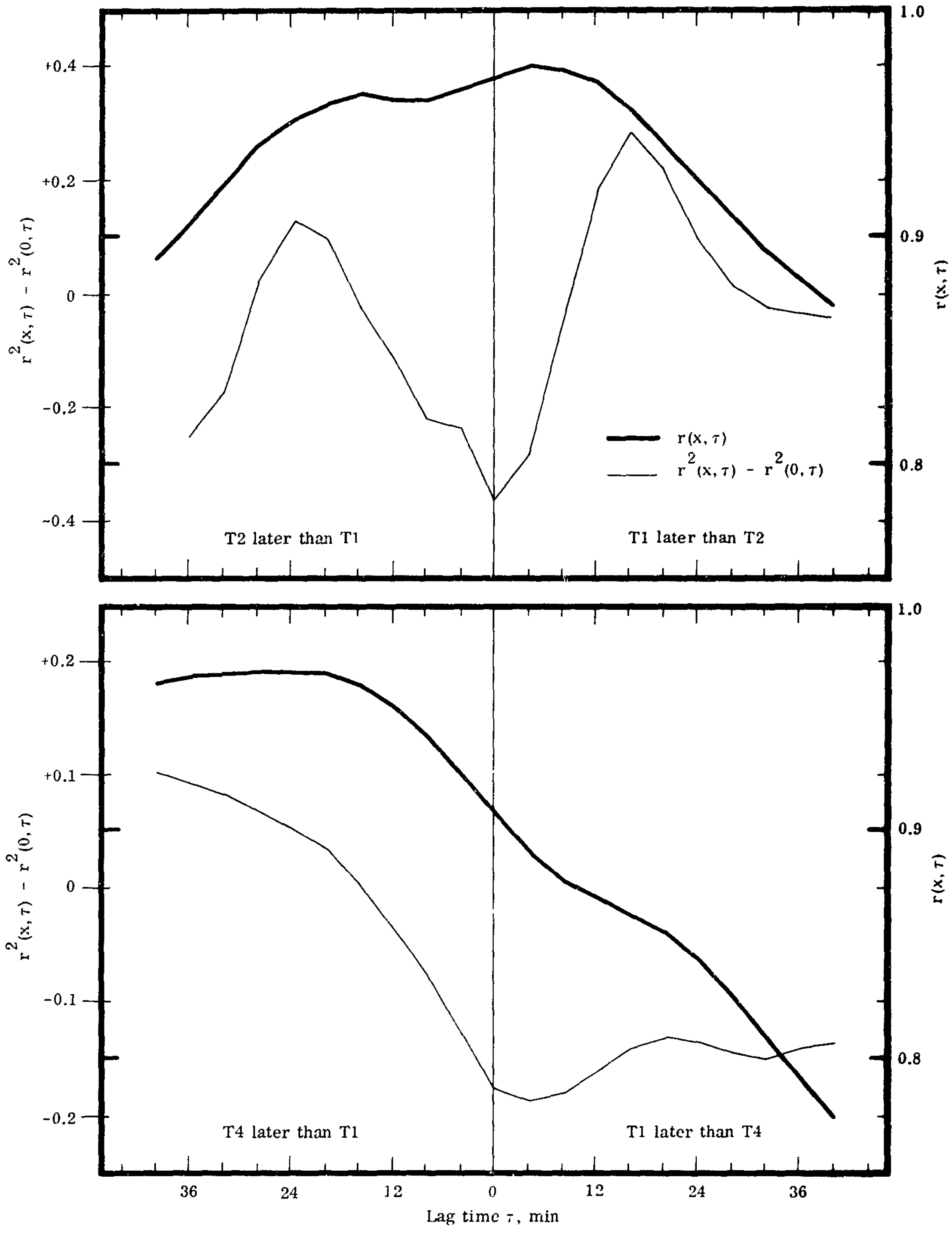

Fig. 3. Correlation curves for lagged time series observations of transmission at station pairs T1–T2 and T1–T4 for the time period 1400 to 1800 on 18 Jan., 1963.

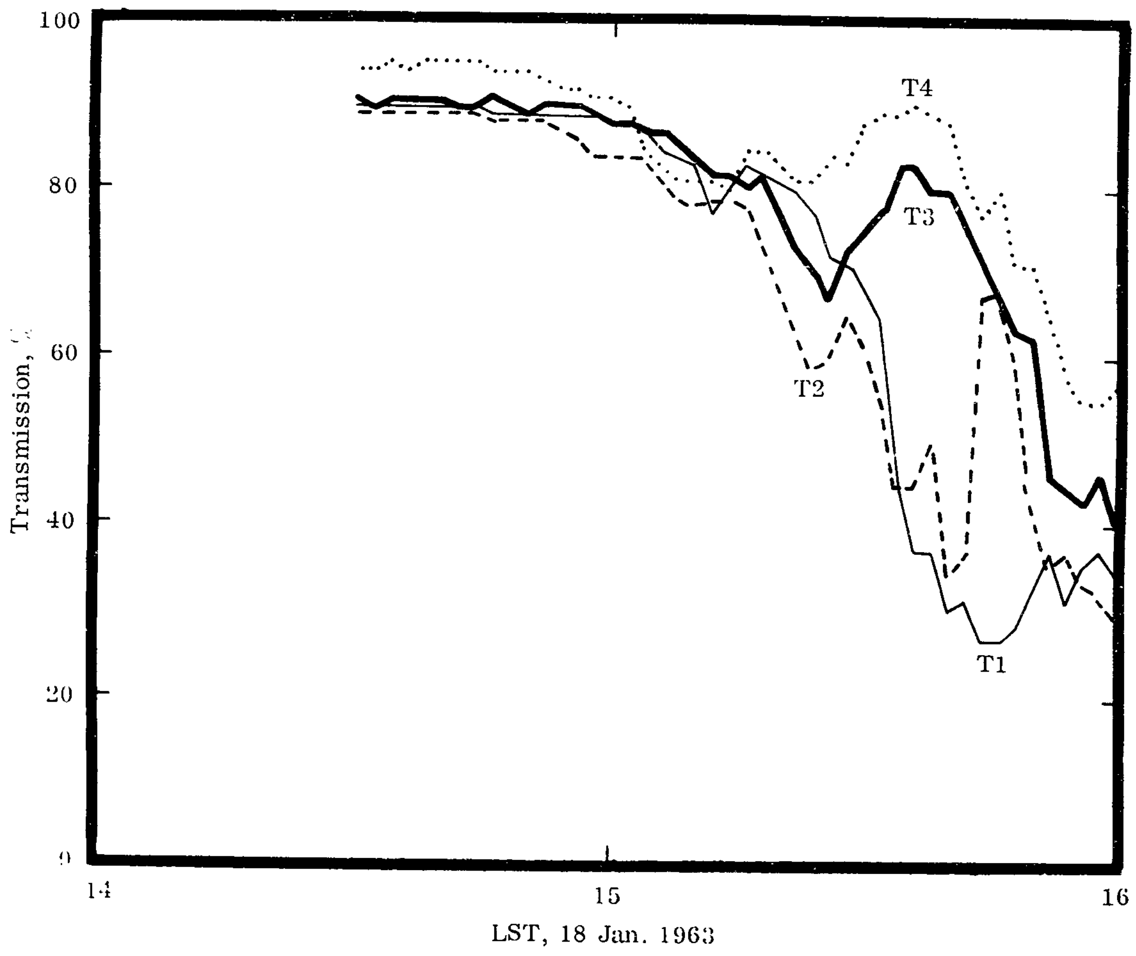

Fig. 4. Transmission curves from each of the four transmissometers along runway 13–31 at Atlantic City, N. J., for the period 1430–1600 on 18 Jan., 1963.

3.0 FOG—4, 5, 6 MARCH 1963

The onset of fog between 2100 and 2200 on 4 March, 1963 at mesonetwork stations 1, 3, 7 and 12 was accompanied by continuous rain of variable intensity. The fog ended between 0230 and 0400 on 5 March at all 4 stations. Wind speeds reported on the hourly airways observations at Atlantic City (near station 1) were 3 knots or less from 2100 to 0000 hours followed by north-northwest winds of 4 to 5 knots until 0300. After 0300, northeast winds of 10 knots or more were reported.

Space and time correlation analysis of the transmission data from the 4 stations indicated an apparent movement of the field from station 12 to station 1 in agreement with the direction of air movement from the north. The indicated lag times between different station pairs were not consistent, however. Furthermore, the wind speeds and directions reported on the hourly airways reports were not in agreement with the reported winds at station 1 nor were the winds at station 1 in agreement with those at stations 3 and 7. In view of the uncertainties in even the gross features of the low-level air flow during the fog no conclusions can be drawn regarding the relative importance of movement of the transmission field.

A low overcast with ceilings of 200 to 700 feet and with visibilities of 1 to 3 miles was reported at Atlantic City in the early morning hours on 6 March. At about 0830 fog was reported at station 1 following an interval of moderate rain. On the basis of a rough analysis of available wind and pressure data from mesonet stations and surrounding airways stations the air flow was estimated to be from the south in the vicinity of Atlantic City and from the east in the northwest portion of the mesonetwork. The mean wind directions during the period 0830 to 1130 at stations 1 and 7 were 175 and 090 degrees, respectively. The transmission curves for stations T1 and T3 and for stations 7 and 12 are shown in Figs. 5 and 6 for this time period. The apparent motion of the transmission field from T1 to 3 to 7 to 12 is consistent with the air movement from south and east. The rather abrupt change in the shape of the transmission curves between

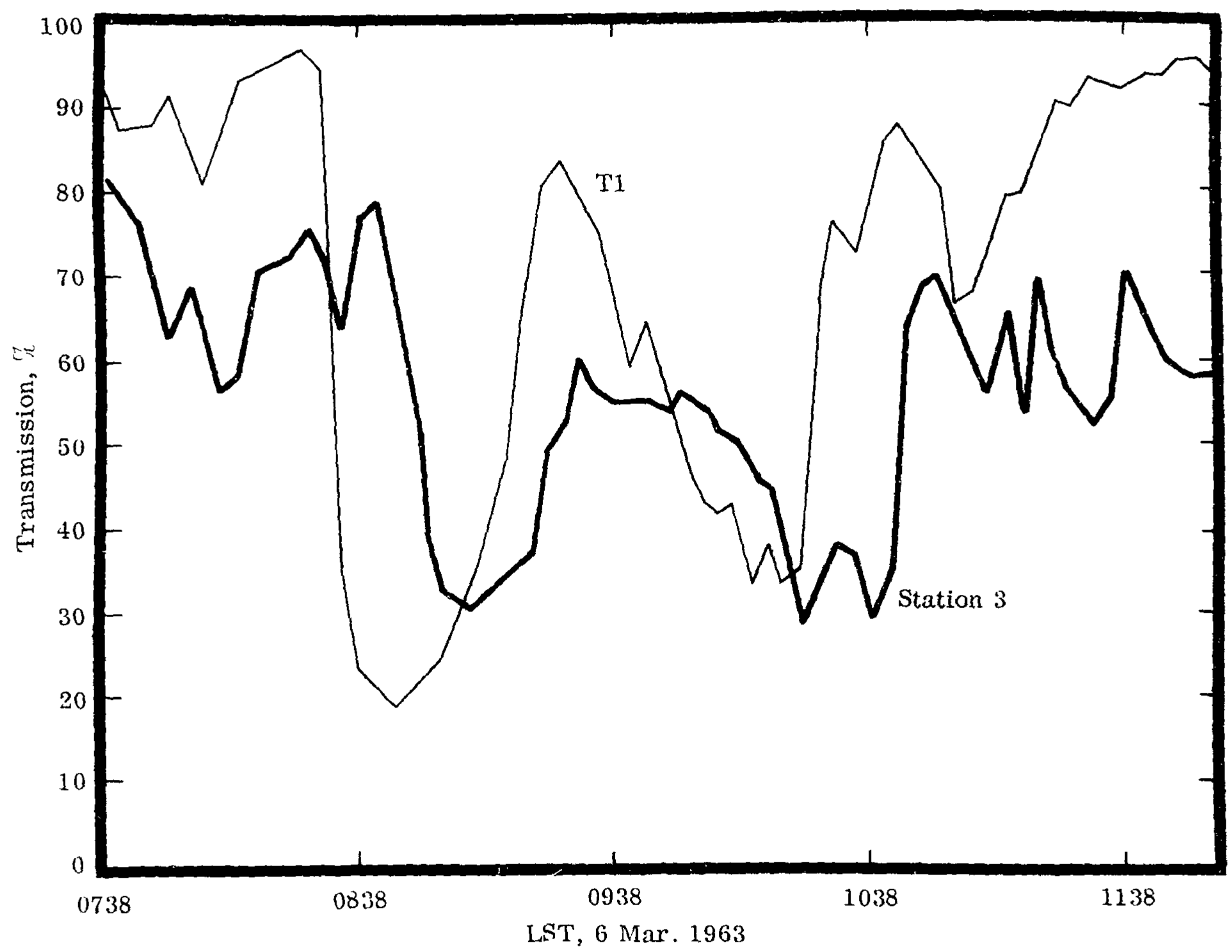

Fig. 5. Transmission observation in fog on 6 March 1963.

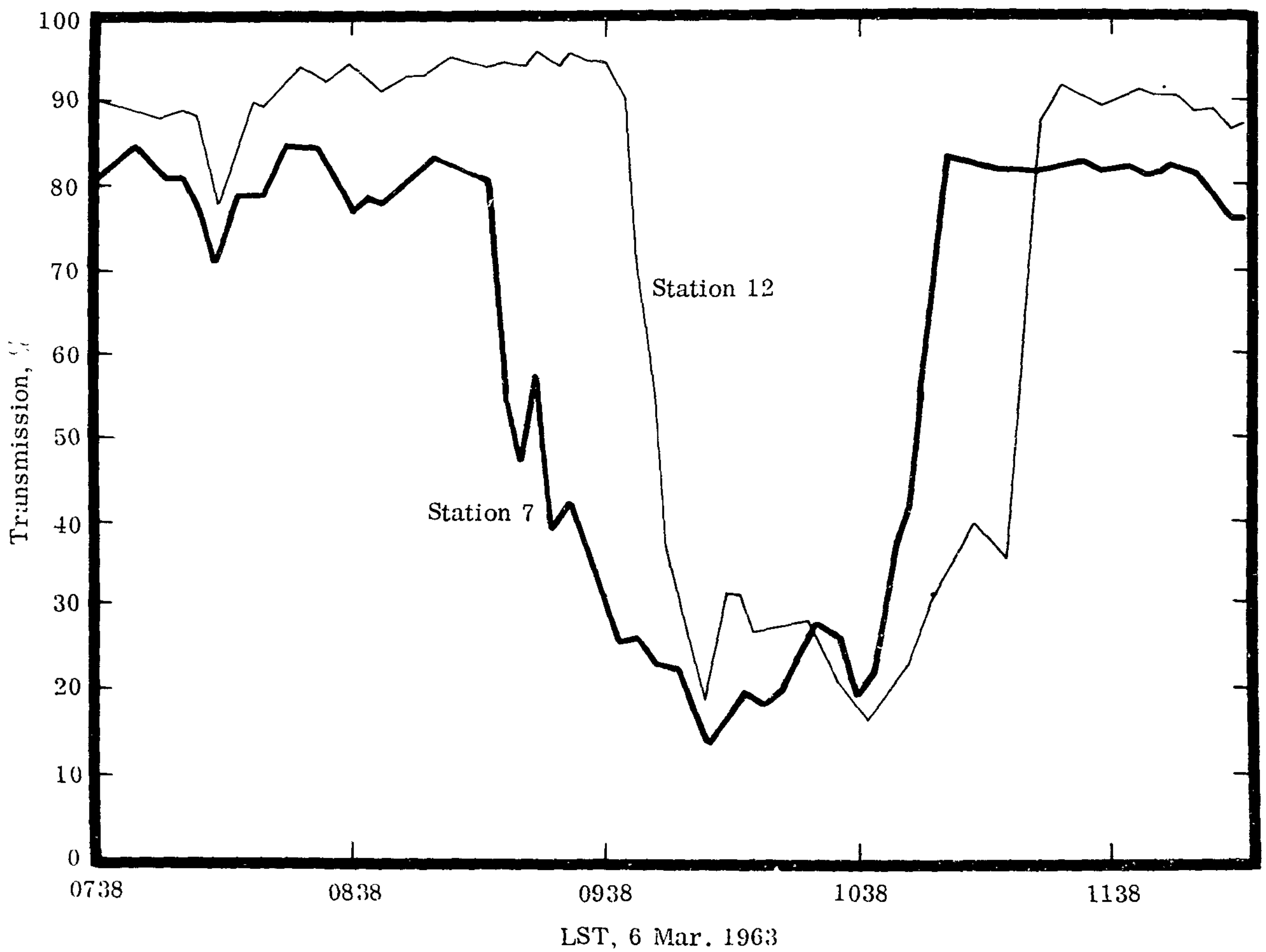

Fig. 6. Transmission observation in fog on 6 March, 1962.

stations 3 and 7 may have been due to the presence of a quasistationary front and the associated discontinuity in the direction of air flow between these two stations. Although a front was shown in this area on the surface synoptic charts its precise location was uncertain due to lack of data.

4.0 RAINSTORM-19–20 MARCH 1963

Rain commenced at about 2000 on 19 March at Millville, N. J. (Station 13) and Atlantic City, N. J. (Station 1). According to the hourly airways observations the rain reached moderate intensities shortly after midnight and changed to continuous drizzle near 0400 on 20 March. Low cloud and thin fog accompanied the precipitation. Surface winds were easterly at 5 to 10 knots at both stations throughout the storm.

Simultaneous observations of rainfall amount and transmission from mesonetwork station 13 during part of the storm are shown in Fig. 7. With the exception of a low value at 0055 all minimum transmission readings can be identified with a local maximum in rainfall rate. This suggests that the principal contribution to variations in transmission was provided by variations in rainfall intensity during the period shown in the figure. Concurrent observations of transmission and rainfall rate for stations 1 and 13 are shown in Fig. 8. Sixteen-minute running means of rain count for consecutive 4 minute intervals are shown in the lower half of the figure. It is evident that 3 principal showers fell at each station and that these showers can be tracked from station 13 to station 1 if some allowance is made for changes in peak intensity during the movement. Although the correspondence between the two transmission curves is less striking there appears to be some evidence of movement of the field from station 13 to station 1.

The quantities $r(x, \tau)$ and $r^2(x, \tau) - r^2(0, \tau)$ (see Section 2.0) are shown in Fig. 9 for the time series observations of transmission and smoothed rainfall rate at stations 13 and 1 in Fig. 8. The speed of movement of the fields of the two variables is bounded by $c_1 = x/\tau_1$ and $c_2 = x/\tau_2$ where τ_1 and τ_2 are given by Eqs. (1) and (2). For the transmission data in Fig. 9 we find $\tau_1 = 24$ min. and $\tau_2 = 28$ min. and for the rainfall rate field $\tau_1 = 20$ min. and $\tau_2 = 24$ min. An average value of $\tau = 24$ min. together with the station separation distance $x = 28$ statute miles yields a speed of 70 mph for the horizontal movement of the two fields. According to the Atlantic City rawinsonde observations at 0630 on 20 March a wind speed of 70 mph was attained at a level between 15,000 and 16,000 feet. The direction at that altitude was 256° or within less than

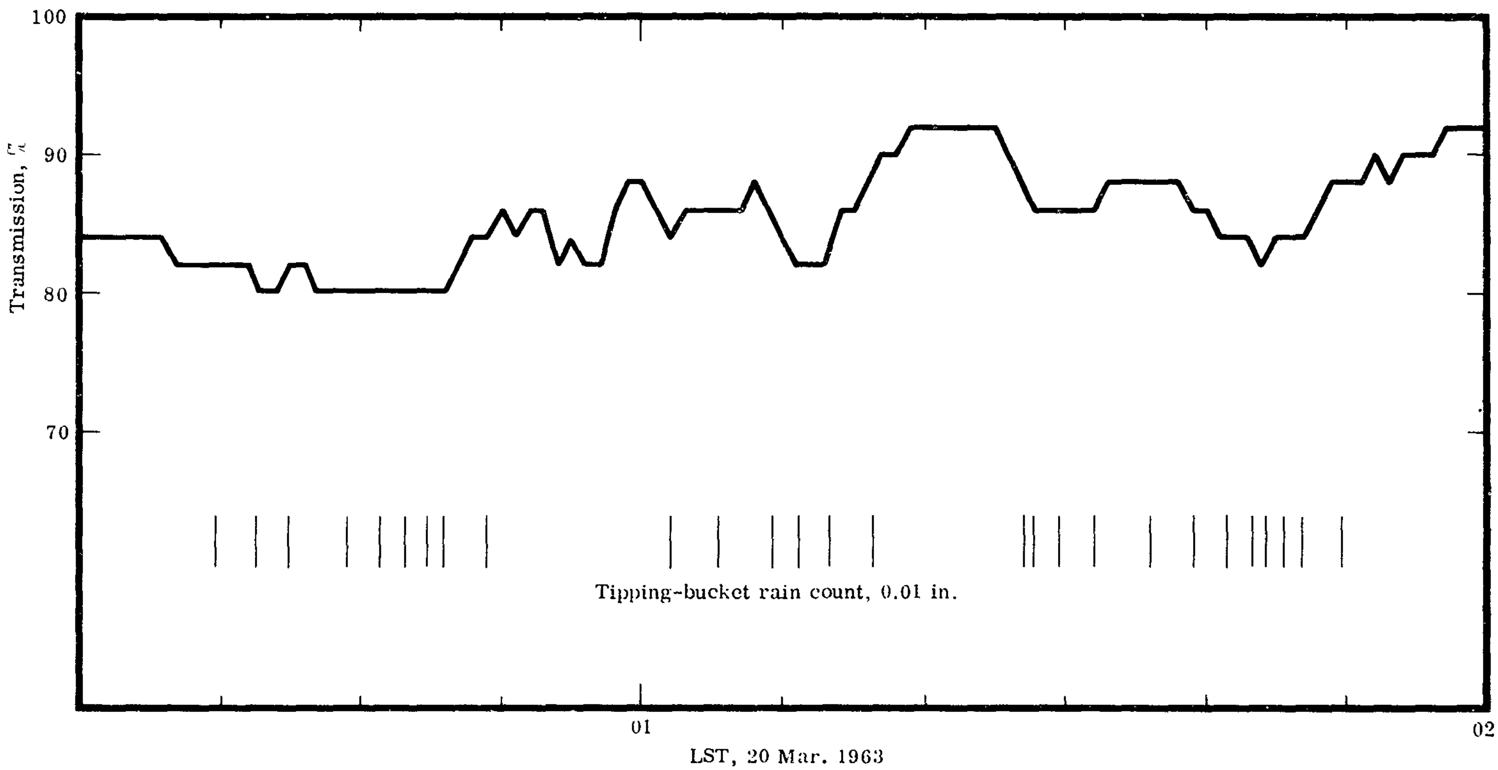

Fig. 7. Concurrent observations of transmission and rainfall amount at mesonetwork station 13 on 20 Mar., 1963.

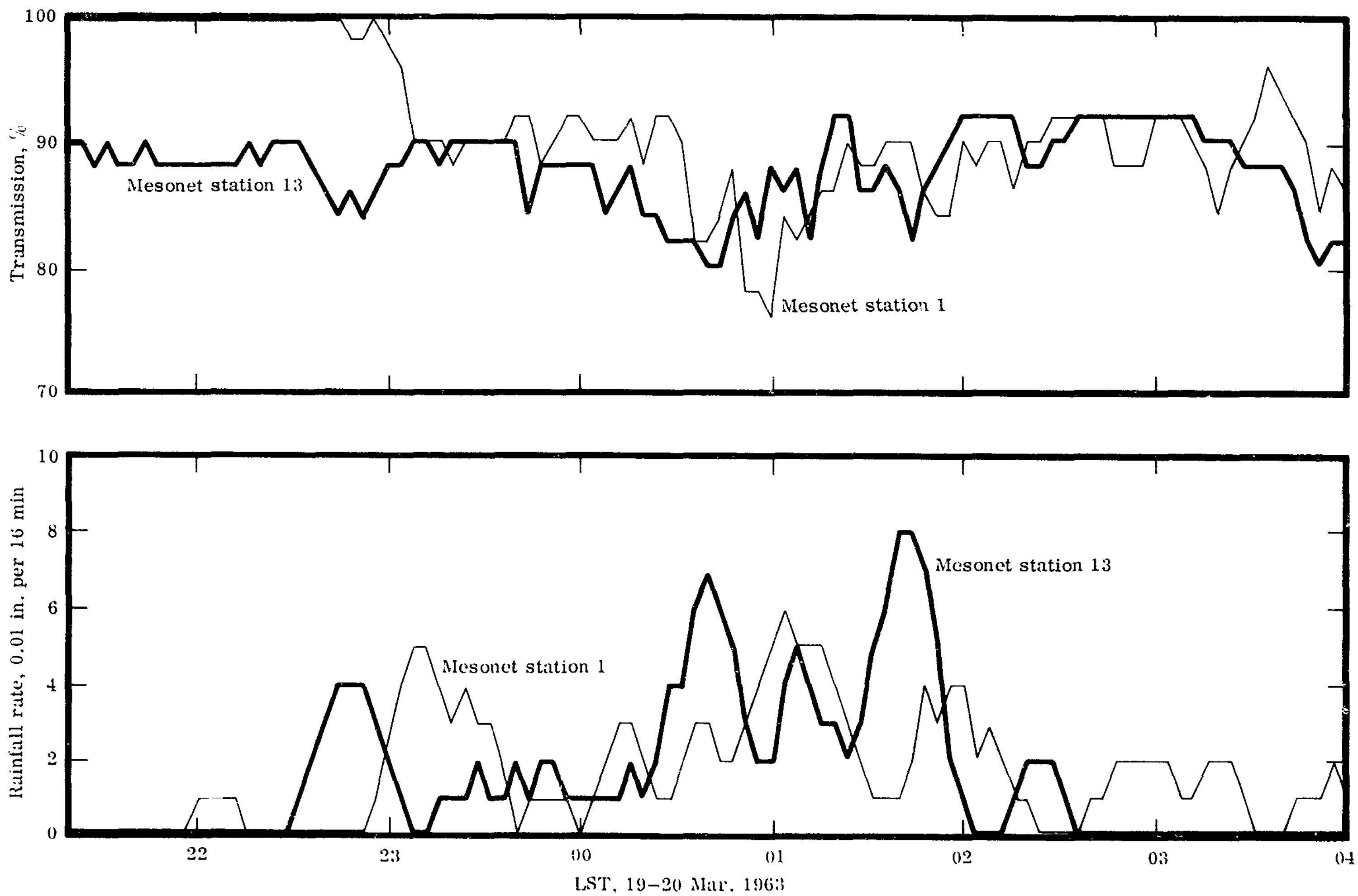

Fig. 8. Concurrent observations of transmission and smoothed rainfall rate at stations 1 and 13 on 19–20 Mar., 1963

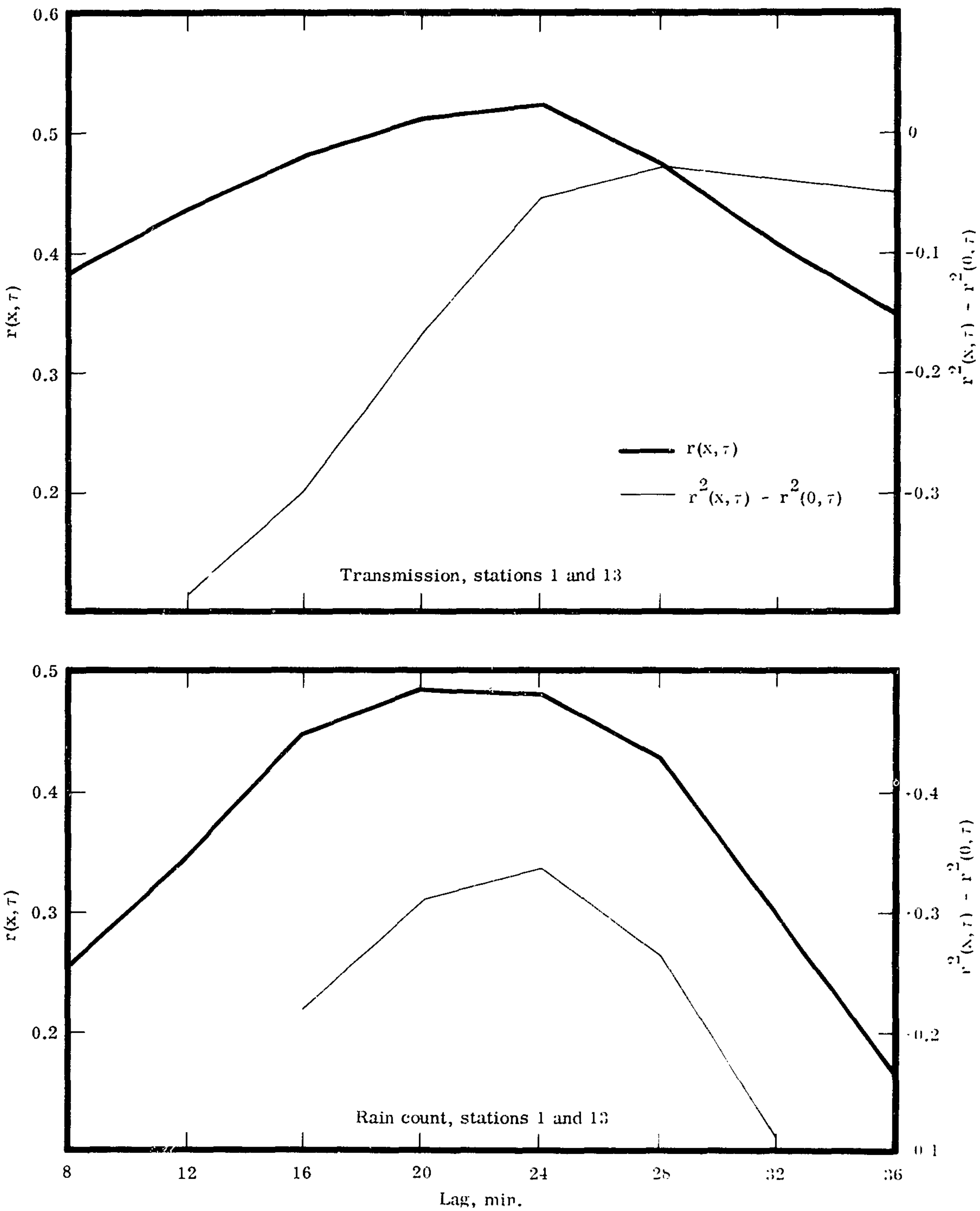

Fig. 9. Lag correlation coefficients for time series observations of transmission and smoothed rainfall rate at stations 1 and 13 on 19–20 Mar., 1963.

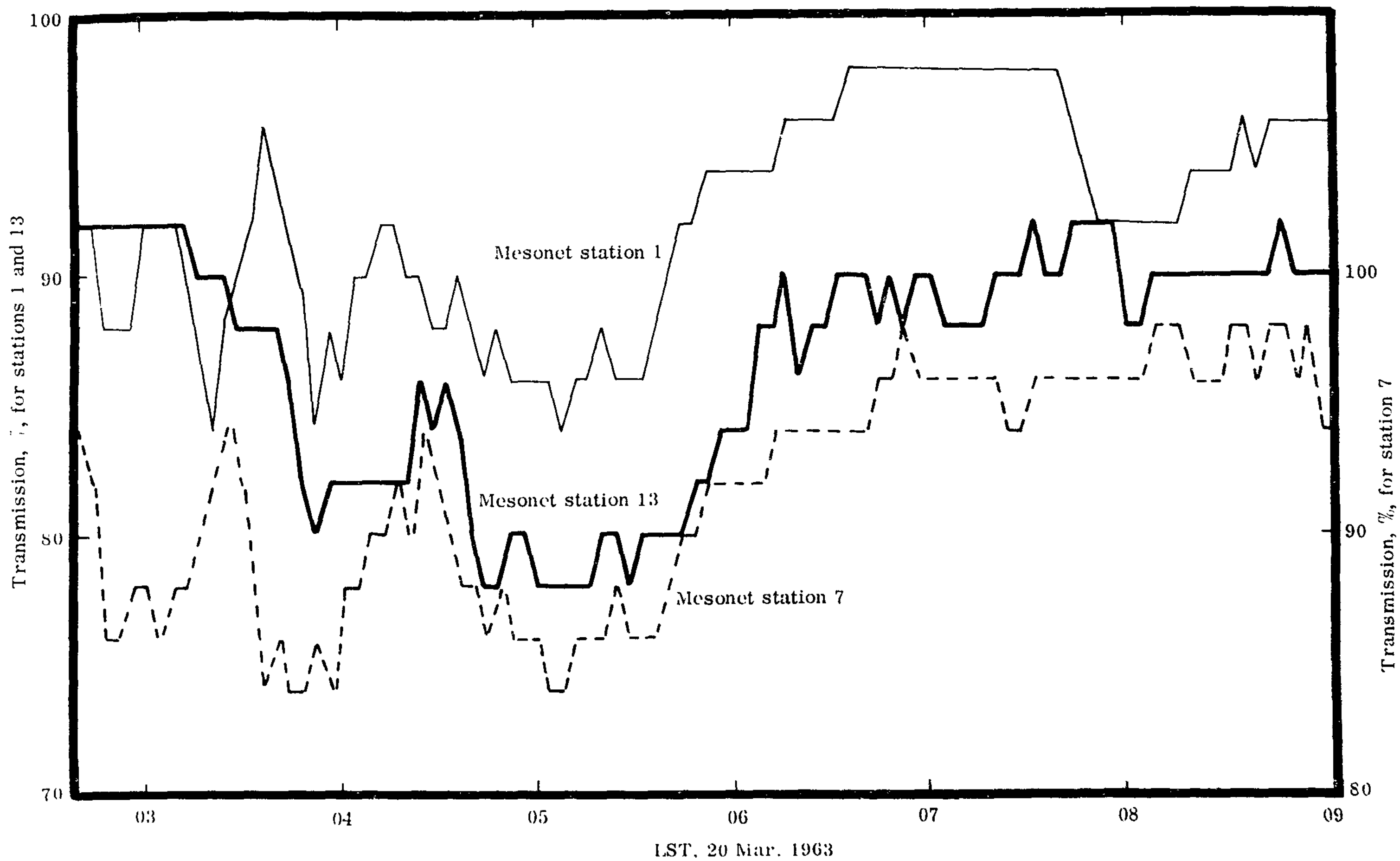

Fig. 10. Concurrent observation of transmission at stations 1, 7, and 13 on 20 March, 1963.

10 degrees of the direction of a straight line from station 13 to station 1. This wind speed and direction was also very similar to the mean layer wind from 700 mb to 500 mb.

As noted earlier, continuous drizzle was reported at both stations from about 0400 to between 0600 and 0700. In a previous study of transmission observations along a runway (3) no success was achieved in attempts to detect a significant translation component in transmission variations during periods of continuous drizzle. Space autocorrelation coefficients for simultaneous observations of transmission in drizzle decayed extremely slowly with distance indicating the presence of variations on scales that were large relative to the runway length. Transmission readings at stations 1, 7, and 13 during the drizzle period and adjacent time intervals are shown in Fig. 10. Although the mesonetwork rain gages are not responsive to the occurrence of drizzle and hence no precipitation was recorded at the time, it appears likely that the minimum transmission values near 0500 were associated with the drizzle that was reported by observers at Millville and Atlantic City. The similarity of the patterns from 0400 to 0615 is indicative of a space scale in excess of 20 to 30 miles. The simultaneity of the patterns is indicative of lack of movement. From these observations it must be concluded that the time variations of transmission in this occurrence of drizzle were dominated by developmental processes of large space scales. In this connection it appears likely that a study of the low-level convergence and vertical motion fields during continuous drizzle events would be fruitful.

5.0 RAINSTORM–26 MARCH 1963

Rain of variable intensity was reported on the hourly airways observations at Atlantic City, N. J. from 1900 on 26 March to 0000 on 27 March. Simultaneous observations of rainfall rate and transmission during the most intense precipitation are shown in Fig. 11. In this example the local rainfall rates are much greater than those shown in Fig. 7 and the concurrent transmission values are lower. Although observations were available from stations 1, 3, 4, 7, 9, and 12 it was not possible to identify individual showers from one station to another with confidence except over the relatively short distance of 4.3 mi from stations 1 to 4. Since upper level wind observations were not available from Atlantic City during this storm no quantitative estimates of the movement or lifetime of the showers were attempted.

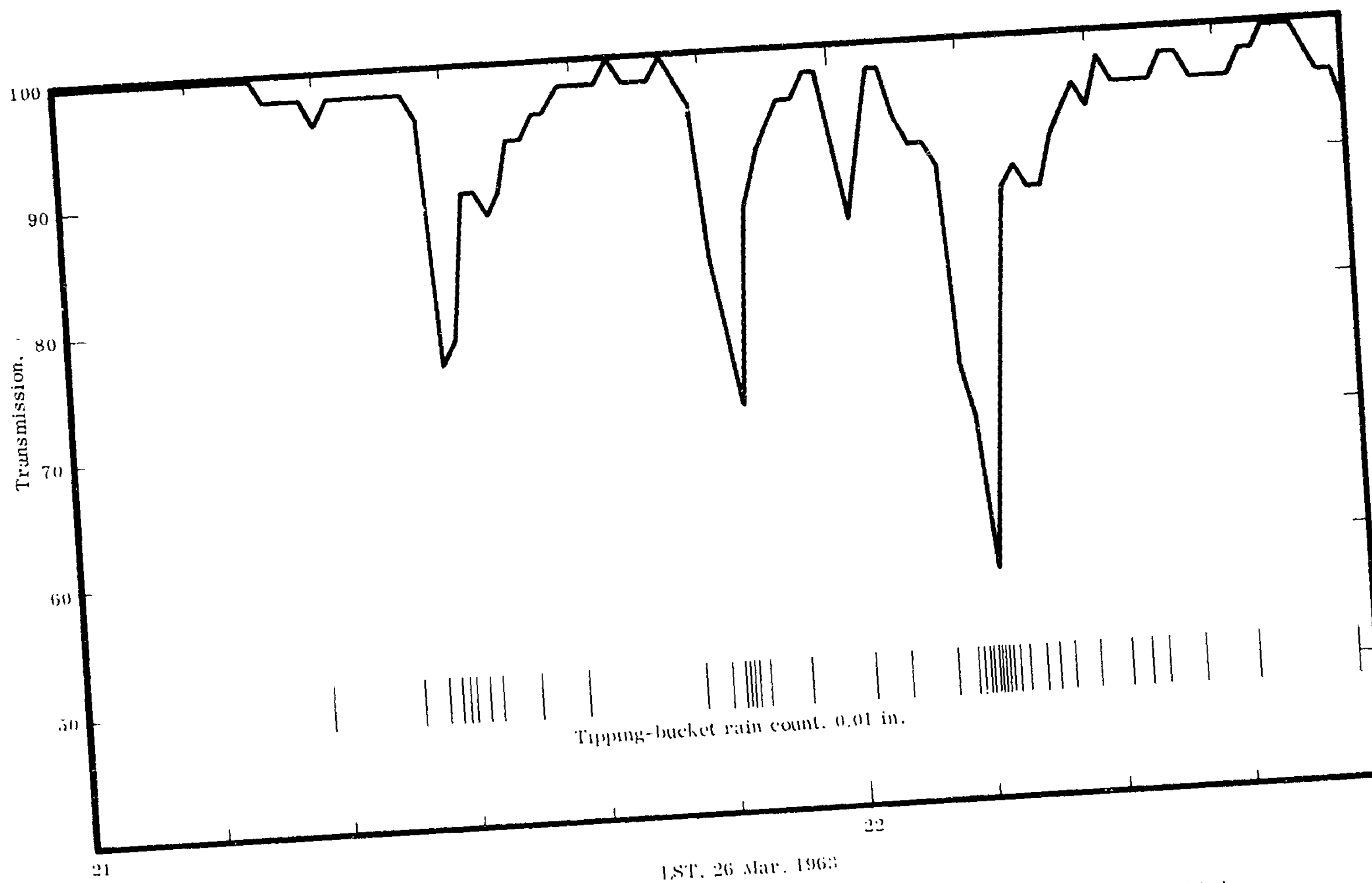

Fig. 11. Concurrent observations of transmission and rainfall amount at station 1 on 26 Mar. 1963

6.0 FOG–2 APRIL 1963

Light rain and drizzle and lowering ceilings preceded the appearance of fog between the hours of 0430-0530 on 2 April 1963 in the Atlantic City area. Calm winds were reported from both Atlantic City and Millville until the fog lifted at about 0700. At this time the wind increased to about 6 knots. Observations of transmission from mesonet stations 2, 3, 12, and 13 are shown in Fig. 12. It is evident from Fig. 12 that the concurrent observations of transmission at stations 2, 3, 12, and 13 are quite similar in form with the exception of the changes in transmission at station 12 during the onset of fog. These data suggest that the variations in transmission in time and space were mainly due to development and that the space scale of the low frequency variations was relatively large.

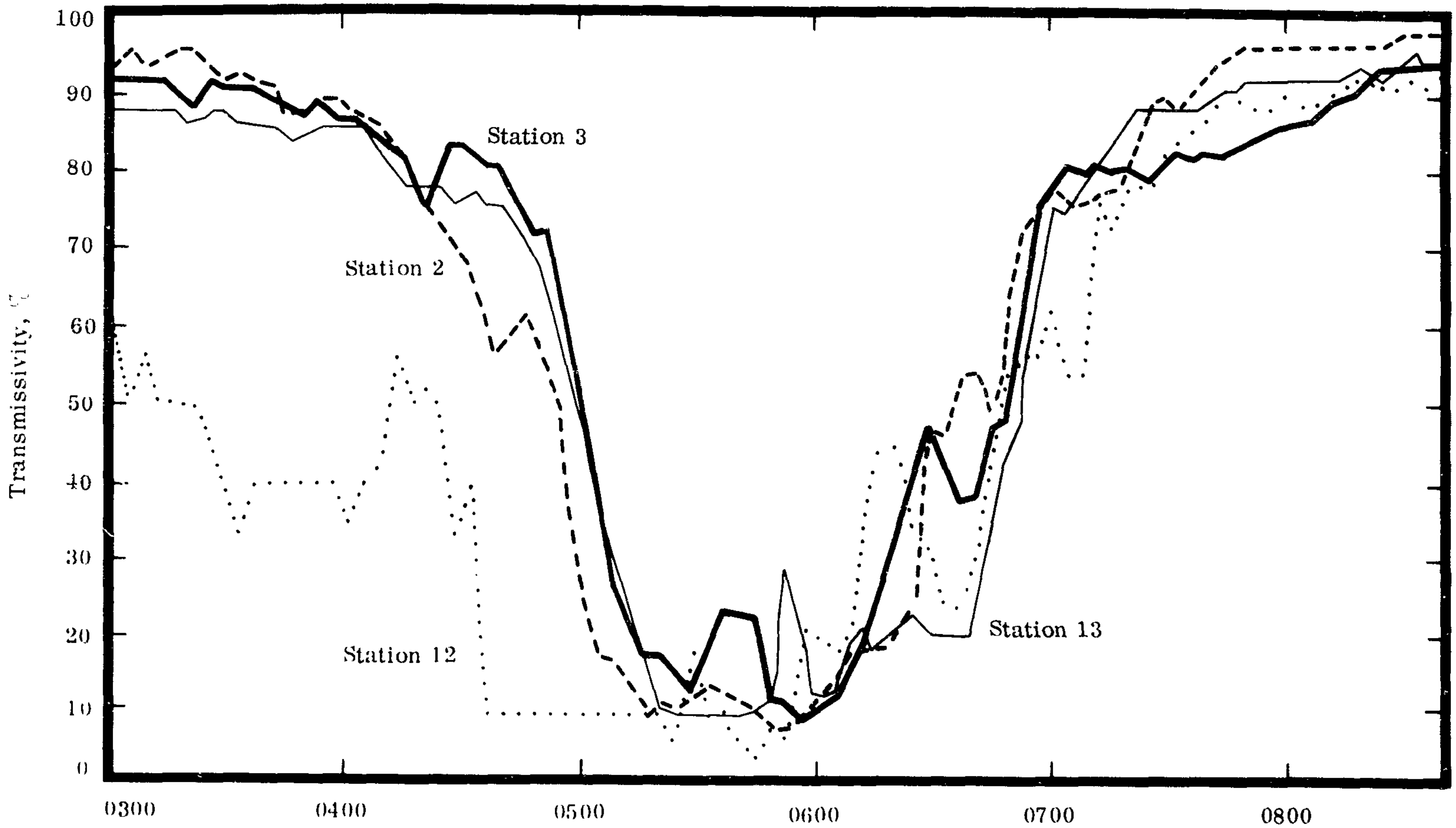

Fig. 12. Transmission observations in fog on 2 April, 1963.

7.0 FOG–3-4 APRIL 1963

During the period 2200-0400 on 3–4 April 1963, fog was reported at several stations within the mesonetwork. No precipitation was reported prior to or during the fog period. Surface winds were easterly at 3-6 knots at Atlantic City, Millville, and mesonet station 7 until about 0100, after which time they became light (< 3 knots) and variable.

Conventional surface analyses in this period indicated the existence of a quasistationary front with stable frontal waves in the mesonetwork area. Evidence of the activity in the pressure and wind fields at station 7 is shown in Fig. 13. Transmission curves for selected stations are shown in Figs. 14 and 15.

The transmission curves in Fig. 14 for stations T1 and T3 with a relatively short separation distance of 1.2 mi are fairly similar and indicate motion of the transmission field from east to west in agreement with the reported surface winds. Over somewhat larger distances of the order of 4 to 8 mi, however, as shown in Fig. 15, the transmission curves are quite dissimilar. It is apparent that station spacings of the order of 2 to 4 mi would be required for adequate description of the complex transmission and air flow patterns in this example.

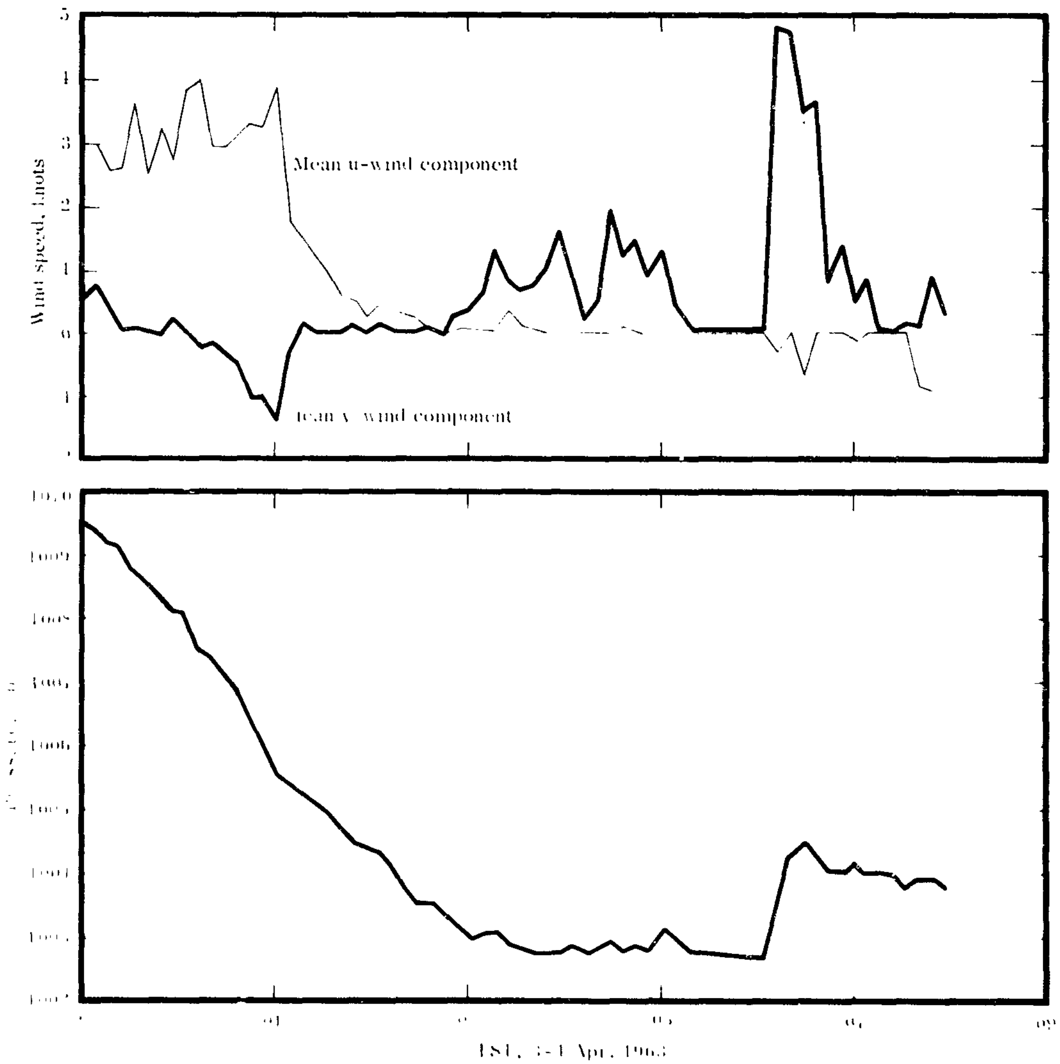

Fig. 17. Station pressure and wind observations during low visibility conditions in fog on 3-4 April 1963.

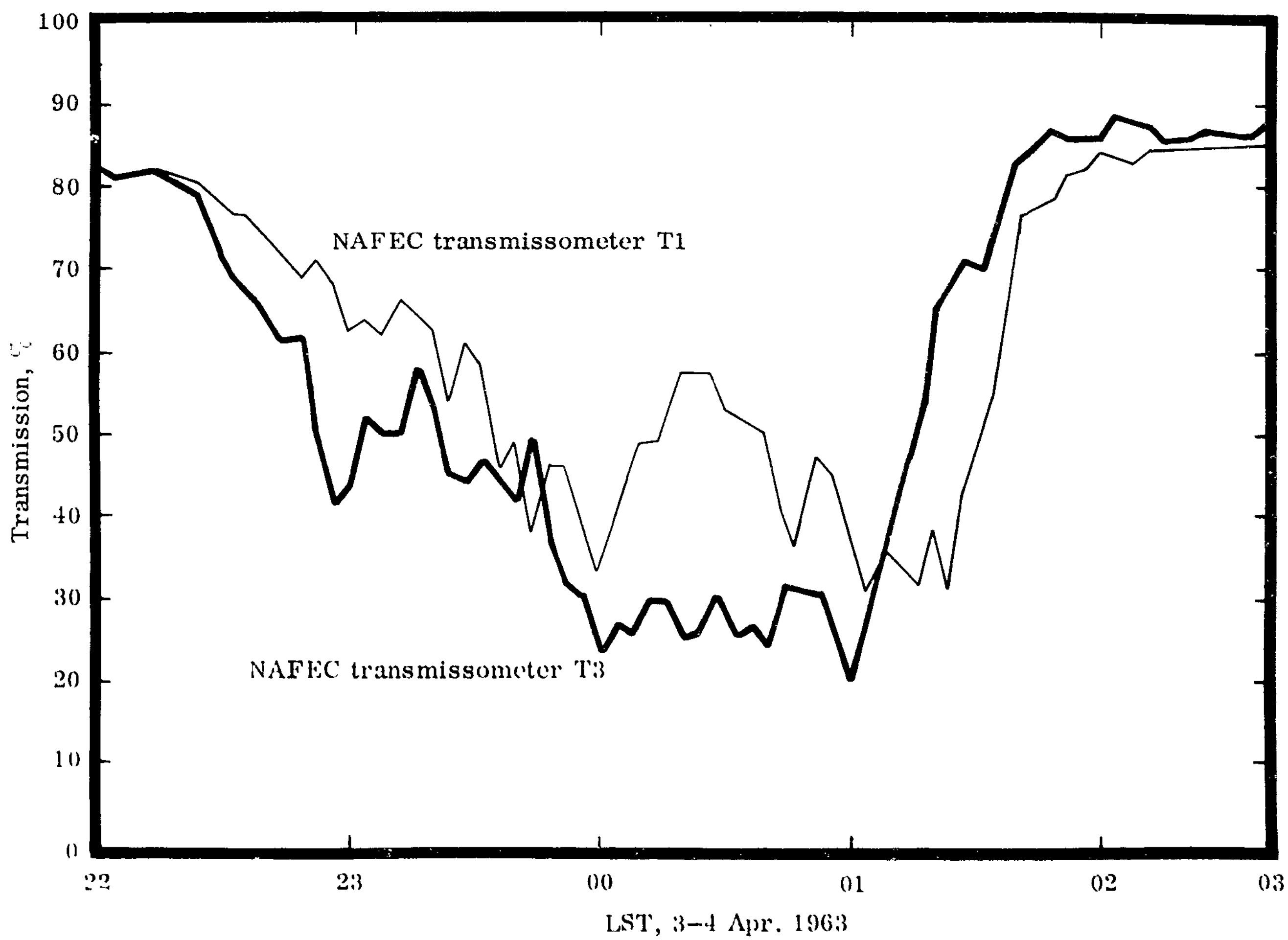

Fig. 14. Transmission observation in fog on 3–4 April, 1963.

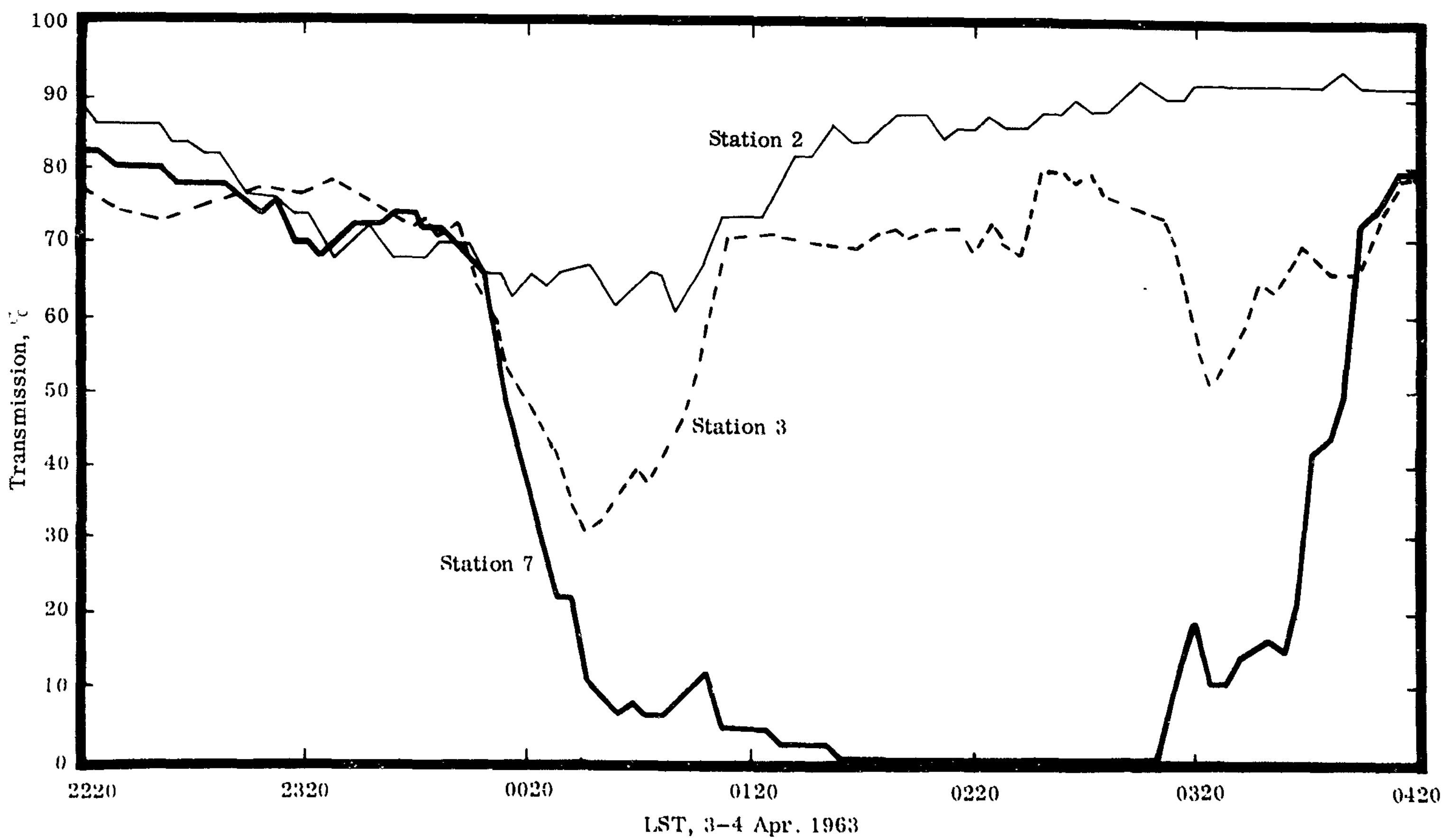

Fig. 15. Transmission observation in fog on 3–4 April, 1963.

8.0 SUMMARY OF RESULTS

A total of 18 data collections taken in the months of January through April, 1963 by automatic weather stations in the mesonetwork of the Federal Aviation Agency at Atlantic City, N. J. have been examined and discussed in this note and in a previous note (2). The collections represent the initial multiple station output from an experimental network. In most instances data were received only from a limited number of stations in the northern and western quadrants of the network area. In the reports attention was directed to transmission, rainfall rate, and wind data since the temperature, dew-point temperature, and cloud base height observations were not considered to be satisfactory for analysis.

The principal aim of these preliminary studies has been to extend previous studies (3) of the time and space scales and of the movement of the field of runway transmission to larger scales more appropriate to the 20 min to 2 hr terminal weather prediction problem. A total of 13 events involving relatively low and variable transmission were found in the 18 data collections. These included fog, continuous rain and rain showers, falling snow, and continuous drizzle as the principal obstructions to vision.

Evidence of horizontal movement of the transmission field was found in 9 of the 13 events. These ranged from highly conservative movement for time periods of a few hours in the case of straight and steady air flow to movement which could be followed for periods of a few minutes only in the case of unsteady, weak air motion with speeds of less than 4 to 5 mph. Within the limits of resolution of the data and analysis techniques it appeared that the direction of movement of the transmission field in fog corresponded well with the surface wind direction but that the speed was somewhat greater than the wind speed over distances in excess of runway length. The lack of exact correspondence between true physical advection and the observed movement of the transmission field for time periods in excess of a few minutes is not surprising in view of the likelihood that individual

fog droplets or parcels will be filtered out in the forest cover, evaporated, or precipitated. An explanation that may account for the results in (3) and in the present study is that the movement of high frequency, small-scale variations of transmission in fog corresponds well with true physical advection over short times and distances and that the movement of intermediate frequency variations of transmission reflects the existence of relatively long-lived fog formation and dissipation processes which are intimately related to the low-level air flow (e.g., vertical motion patterns, turbulent mixing of heat and water vapor). Extrapolating to low frequency variations in transmission it may be anticipated that the movement of an entire fog occurrence considered as one low-frequency wave will reflect the movement of the synoptic-scale vertical motion, water vapor, and precipitation fields that supply a suitable setting for the formation and dissipation of the fog. The preceding remarks may not apply to true radiation fog including ground fog which normally occurs with wind speeds of less than 4 to 5 mph.

The present study has shown the existence of important variations of transmission in fog over distances of the order of 3 to 6 mi in association with frontal wave activity. Due to insufficient data it was not possible to conduct definitive studies which would indicate whether these variations were the result of similar small scale variations in horizontal air flow or whether they reflected the presence of short-lived development and dissipation processes.

Studies of variations of transmission in rain and snow revealed the existence of small-scale intense showers with very short lifetimes as well as large-scale showers with lifetimes of at least 20 to 30 min. The movement of the transmission field in such cases apparently reflected the movement of the generating cells or bands aloft. Speeds as high as 70 mph were observed.

The variations of transmission in continuous drizzle were indicative of large scale (tens of miles) non-advective processes in agreement with the findings in reference (3).

9.0 REFERENCES

1. Federal Aviation Agency, Mesometeorological Network Description, 22 pp., 1962.

2. Hage, K. D., H. D. Entrekin, and A. F. Boyer, Jr., Preliminary Studies of Atmospheric Transmissivity Data from the Federal Aviation Agency Atlantic City Mesonetwork. Tech. Note attached to the Apr. 1963 Progress Rpt. under Contract FAA/BRD-363, The Travelers Research Center, Inc., Hartford, 25 pp., Apr. 1963.

3. Hage, K. D., H. D. Entrekin, and A. E. Boyer, Jr., Space and Time Variation in Atmospheric Transmission at a Runway. Tech. Publ. 28, Contract FAA/BRD-363, The Travelers Research Center, Inc., 52 pp., Hartford.

4. Personal Communication, May, 1963.